Issued May 25, 1907.

U. S. DEPARTMENT OF AGRICULTURE,

OFFICE OF EXPERIMENT STATIONS—BULLETIN 185.

A. C. TRUE, Director.

IRON IN FOOD

AND

ITS FUNCTIONS IN NUTRITION.

BY

H. C. SHERMAN, Ph. D.,

Professor of Organic Analysis, Columbia University.

Special
Request

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN.

NOTE.—For those publications to which a price is affixed application should be made to the Superintendent of Documents, Government Printing Office, Washington, D. C., the officer designated by law to sell Government publications. Publications marked with an asterisk (*) are not available for distribution

*Bul. 21. Methods and Results of Investigations on the Chemistry and Economy of Food. By W. O. Atwater. Pp. 222. Price, 15 cents.

Bul. 28. (Revised edition.) The Chemical Composition of American Food Materials. By W. O. Atwater and A. P. Bryant. Pp. 87. Price, 5 cents.

Bul. 29. Dietary Studies at the University of Tennessee in 1895. By C. E. Wait, with comments by W. O. Atwater and C. D. Woods. Pp. 45. Price, 5 cents.

*Bul. 31. Dietary Studies at the University of Missouri in 1895, and Data Relating to Bread and Meat Consumption in Missouri. By H. B. Gibson, S. Calvert, and D. W. May, with comments by W. O. Atwater and C. D. Woods. Pp. 24. Price, 5 cents.

Bul. 35. Food and Nutrition Investigations in New Jersey in 1895 and 1896. By E. B. Voorhees. Pp. 40. Price, 5 cents.

*Bul. 37. Dietary Studies at the Maine State College in 1895. By W. H. Jordan. Pp. 57. Price, 5 cents.

Bul. 38. Dietary Studies with Reference to the Food of the Negro in Alabama in 1895 and 1896. Conducted with the cooperation of the Tuskegee Normal and Industrial Institute and the Agricultural and Mechanical College of Alabama. Reported by W. O. Atwater and C. D. Woods. Pp. 69. Price, 5 cents.

Bul. 40. Dietary Studies in New Mexico in 1895. By A. Goss. Pp. 23. Price, 5 cents.

Bul. 43. Losses in Boiling Vegetables and the Composition and Digestibility of Potatoes and Eggs. By H. Snyder, A. J. Frisby, and A. P. Bryant. Pp. 31. Price, 5 cents.

Bul. 44. Report of Preliminary Investigations on the Metabolism of Nitrogen and Carbon in the Human Organism with a Respiration Calorimeter of Special Construction. By W. O. Atwater, C. D. Woods, and F. G. Benedict. Pp. 64. Price, 5 cents.

Bul. 45. A Digest of Metabolism Experiments in which the Balance of Income and Outgo was Determined. By W. O. Atwater and C. F. Langworthy. Pp. 434. Price, 25 cents.

*Bul. 46. Dietary Studies in New York City in 1895 and 1896. By W. O. Atwater and C. D. Woods. Pp. 117. Price, 10 cents.

Bul. 52. Nutrition Investigations in Pittsburg, Pa., 1894–1896. By Isabel Bevier. Pp. 48. Price, 5 cents.

Bul. 53. Nutrition Investigations at the University of Tennessee in 1896 and 1897. By C. E. Wait. Pp. 46. Price, 5 cents.

*Bul. 54. Nutrition Investigations in New Mexico in 1897. By A. Goss. Pp. 20. Price, 5 cents.

Bul. 55. Dietary Studies in Chicago in 1895 and 1896. Conducted with the cooperation of Jane Addams and Caroline L. Hunt, of Hull House. Reported by W. O. Atwater and A. P. Bryant. Pp. 76. Price, 5 cents.

Bul. 63. Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body. By W. O. Atwater and E. B. Rosa. Pp. 94. Price, 10 cents.

*Bul. 66. The Physiological Effect of Creatin and Creatinin and their Value as Nutrients. By J. W. Mallet. Pp. 24. Price, 5 cents.

Bul. 67. Studies on Bread and Bread Making. By Harry Snyder and L. A. Voorhees. Pp. 51. Price, 10 cents.

Bul. 68. A Description of Some Chinese Vegetable Food Materials and Their Nutritive and Economic Value. By W. C. Blasdale. Pp. 48. Price, 10 cents.

Bul. 69. Experiments on the Metabolism of Matter and Energy in the Human Body. By W. O. Atwater and F. G. Benedict, with the cooperation of A. W. Smith and A. P. Bryant. Pp. 112. Price, 10 cents.

*Bul. 71. Dietary Studies of Negroes in Eastern Virginia in 1897 and 1898. By H. B. Frissell and Isabel Bevier. Pp. 45. Price, 5 cents.

Bul. 75. Dietary Studies of University Boat Crews. By W. O. Atwater and A. P. Bryant. Pp. 72. Price, 5 cents.

Bul. 84. Nutrition Investigations at the California Agricultural Experiment Station, 1896–1898. By M. E. Jaffa. Pp. 39. Price, 5 cents.

Bul. 85. A Report of Investigations on the Digestibility and Nutritive Value of Bread. By C. D. Woods and L. H. Merrill. Pp. 51. Price, 5 cents.

Bul. 89. Experiments on the Effect of Muscular Work upon the Digestibility of Food and the Metabolism of Nitrogen. Conducted at the University of Tennessee, 1897–1899. By C. E. Wait. Pp. 77. Price, 5 cents.

Bul. 91. Nutrition Investigations at the University of Illinois, North Dakota Agricultural College, and Lake Erie College, Ohio, 1896–1900. By H. S. Grindley and J. L. Sammis, E. F. Ladd, and Isabel Bevier and Elizabeth C. Sprague. Pp. 42. Price, 5 cents.

Bul. 98. The Effect of Severe and Prolonged Muscular Work on Food Consumption, Digestion, and Metabolism, by W. O. Atwater and H. C. Sherman, and the Mechanical Work and Efficiency of Bicyclers, by R. C. Carpenter. Pp. 67. Price, 5 cents.

Bul. 101. Studies on Bread and Bread Making at the University of Minnesota in 1899 and 1900. By Harry Snyder. Pp. 65. Price, 5 cents.

Bul. 102. Experiments on Losses in Cooking Meat, 1898–1900. By H. S. Grindley, with the cooperation of H. McCormack and H. C. Porter. Pp. 64. Price, 5 cents.

Bul. 107. Nutrition Investigations among Fruitarians and Chinese at the California Agricultural Experiment Station, 1899–1901. By M. E. Jaffa. Pp. 43. Price, 5 cents.

Bul. 109. Experiments on the Metabolism of Matter and Energy in the Human Body, 1898–1900. By W. O. Atwater and F. G. Benedict, with the cooperation of A. P. Bryant, A. W. Smith, and J. F. Snell. Pp. 147. Price, 10 cents.

[Continued on third page of cover.]

975 Issued May 25, 1907.

U. S. DEPARTMENT OF AGRICULTURE,

OFFICE OF EXPERIMENT STATIONS—BULLETIN 185.

A. C. TRUE, Director.

IRON IN FOOD

AND

ITS FUNCTIONS IN NUTRITION.

BY

H. C. SHERMAN, Ph. D.,

Professor of Organic Analysis, Columbia University.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1907.

THE OFFICE OF EXPERIMENT STATIONS.

STAFF.

A. C. TRUE, D. Sc., *Director.*

E. W. ALLEN, Ph. D., *Assistant Director and Editor of Experiment Station Record.*

W. H. BEAL, B. A., M. E., *Chief of Editorial Division.*

C. F. LANGWORTHY, Ph. D., *Chief of Nutrition Investigations.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., February 27, 1907.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 185 of this Office a report of investigations on iron in food and its functions in nutrition, carried on at Columbia University, New York City, by H. C. Sherman, professor of organic analysis, as a part of the cooperative nutrition investigations of the Office of Experiment Stations.

In his report Professor Sherman includes a general discussion of iron in food and its functions in nutrition, together with the results of three metabolism experiments in which the balance of income and outgo of nitrogen, iron, phosphorus, calcium, and magnesium were determined, as well as the results of two dietary studies undertaken with special reference to the iron content of the food consumed; and estimates of the amounts of iron taken per man per day in 20 dietary studies made under the auspices of this Office in different parts of the United States. The experimental results obtained are discussed in the light of previous investigations and the report as a whole constitutes a useful summary of data on iron, which is one of the important mineral constituents of food.

Mr. A. J. Mettler, B. S., of the department of chemistry of Columbia University, assisted Doctor Sherman in carrying on the work.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

IRON IN FOOD AND NUTRITION.

INTRODUCTION.

The great importance attached to the protein metabolism by Liebig and Voit and the increasing recognition of energy conceptions in the more recent investigations of nutrition have together resulted in a marked tendency to limit the discussion of nutrition problems to a consideration of protein and energy alone. In terms of the elements, only nitrogen, carbon, hydrogen, and oxygen are ordinarily considered in studies of metabolism and food requirements. That other elements are essential is of course well known, but it has been commonly assumed that they will be present in sufficient quantity in any diet which furnishes the requisite amounts of proteids, fats, and carbohydrates. With the rapid increase in the use of foods poor in ash, this assumption seems no longer safe, and it becomes desirable to consider the so-called ash constituents more carefully than has been customary in the past.

Iron stands in the closest possible relation to the fundamental processes of metabolism, being an essential constituent both of the oxygen-carrying constituents of the blood and of the substances which appear to control the most important activities within the cells. It is therefore of the highest importance that the food shall supply sufficient amounts of iron in forms which are readily assimilated. The studies here reported consider especially the iron requirement in man as indicated by metabolism experiments, the amounts of iron in typical American dietaries, and the extent to which the iron content of the diet can be regulated by selection of food materials. Since the metabolism of iron has not been discussed in any previous publication of this series, an outline of the subject with references to some of the important literature is included in this bulletin.

THE METABOLISM OF IRON IN THE ANIMAL BODY.

THE ABSORPTION AND ASSIMILATION OF DIFFERENT FORMS OF IRON.

It has long been known that iron is essential to the nutrition of animals as well as of plants and that small amounts of the oxid or phosphate of iron occur in the ash of all natural food materials. It

seems to have been assumed that the iron exists in the food as oxid or phosphate, and that hemoglobin is formed in the body by the combination of proteid with inorganic iron. This view was hardly consistent with the ideas of animal metabolism taught by Liebig and generally held at the time, but appeared to be supported by the successful use of inorganic iron in the treatment of anemia. Since hemoglobin contains iron and the ingestion of inorganic iron is often found to increase the hemoglobin content of the blood, it was naturally inferred that the inorganic iron taken medicinally serves for the production of hemoglobin in the body.

The results obtained in a number of investigations published between 1854 and 1884 threw doubt upon the utilization of inorganic iron for the production of hemoglobin, since they indicated that iron salts when injected act as poisons and are quickly eliminated from the blood, and when given by the mouth reappear almost quantitatively in the feces, little, if any, evidence of absorption being obtained except when the doses were so large or long continued as to cause irritation of the intestine.

The view that medicinal iron acts by stimulation of the absorbing membrane was also advocated at about this time. It was held that the amount of iron in the ordinary food is always sufficient for the needs of the body, but that sometimes the intestinal mucous membrane becomes so bloodless that it can not properly perform its functions of absorption. Under such conditions inorganic iron was believed to stimulate and tone up the membrane so that in a short time the increased absorption of food-iron makes good the deficiency in the blood.

A very suggestive paper upon the metabolism of iron, the effects of a lack of iron in the food, and the amounts of iron required for the maintenance of the body in health was published by von Hösslin in 1882,[a] and long before this some attention had been given to the iron content of food materials by Boussingault. Boussingault's figures, however, are not sufficiently accurate to be of value at the present time, and little attention was given to the subject discussed by von Hösslin until it was reopened by Bunge about two years later.

Bunge,[b] in 1884, doubting the ability of the animal body to form hemoglobin from inorganic iron, undertook the study of the iron compounds of food materials in order to find in what form iron is normally absorbed and from what sort of iron compounds the growing organism ordinarily forms its hemoglobin. Yolk of egg does not contain any hemoglobin, but it must contain substances from which hemoglobin can be formed, since the incubation of the eggs results in the development of hemoglobin without the introduction of any-

---

[a] Ztschr. Biol., 18 (1882), p. 612.

[b] Ztschr. Physiol. Chem., 9 (1884–85), p. 49.

thing from without. Bunge found no inorganic iron in egg yolk, but isolated considerable amounts of the precursor of hemoglobin, which he called "hematogen" and which exhibited the properties of a nucleo-albumin, containing about 0.3 per cent of iron in such firm "organic" combination that it gives none of the ordinary reactions of iron salts. In milk, cereals, and legumes similar organic compounds of iron and only traces of inorganic iron were found. In this paper Bunge distinctly stated that iron occurs in food solely in the form of complicated organic compounds which have been built up by the life processes of plants. In this form, he believed, is the iron absorbed and assimilated and from these compounds hemoglobin is produced.

Since milk is the sole food of young mammals during a considerable period of rapid growth, Bunge was surprised to find only small amounts of iron in milk ash. Comparing the composition of the ash of milk with that of the ash of new-born animals of the same species, it was found [a] that, while other constituents occurred in nearly the same proportion in each case, the iron was six times as abundant in the ash of the young animal as in that of the milk on which it was nourished. That the suckling animal grows rapidly and increases its blood supply in spite of this apparent deficiency of iron in its food is due to the fact that the body contains a reserve supply of iron at birth. In confirmation of this statement Bunge and his pupils have published many analyses showing that the percentage of iron in the entire organism is highest at birth and diminishes during the period in which only milk is taken. Zaleski [b] also found that the blood-free liver of a new-born dog was much richer in iron than the livers of full-grown dogs which had been freed from blood in the same manner. On the basis of his own and Zaleski's experiments, Bunge concluded that the absorption and assimilation of iron is difficult; that, of the two ways by which iron can be conveyed from mother to offspring—through the milk glands or the placenta—the latter is preferred as being safer because the iron of the food may be largely lost through defective digestion or through putrefaction in the intestine. Hence a comparatively large amount of iron is stored before birth for use in the formation of hemoglobin during the suckling period. This was found to be the case with dogs, cats, and rabbits. Guinea pigs, however, are born without such a store of iron, for these animals normally eat green leaves, etc. (food rich in organic iron) from the first day of life.

Socin,[c] working in Bunge's laboratory, tested the assimilation of the

---

[a] Ztschr. Physiol. Chem., 13 (1889), p. 399.

[b] Ztschr. Physiol. Chem., 10 (1886), p. 453.

[c] Ztschr. Physiol. Chem., 15 (1890–91), p. 93. This paper contains a large number of references to the earlier literature.

iron of egg yolk by mammals. Mice were divided into groups and fed (1) on food free from iron or containing iron in the form of chlorid only, and (2) on the same food with the addition of egg yolk. None of the mice fed without organic iron lived for more than thirty-two days, while some of those receiving egg yolk lived as long as the experiments were continued (sixty to ninety-nine days) and gained in weight.

Von Hösslin[a] kept growing dogs upon a fixed diet to which was added either organic or inorganic iron, and observed the effect upon the hemoglobin content of the blood. These experiments led him to the conclusion that the organic iron compounds of the food are much more efficient in supplying material for the production of hemoglobin than are equivalent or even much larger quantities of iron in the form of inorganic compounds. As the result of these experiments and of his observations upon children, von Hösslin further concluded that a pure milk diet during the period of rapid growth does not furnish sufficient iron to keep up the hemoglobin content of the blood, and that whenever any tendency toward anemia is observed special attention should be paid to the nature of the food to see that it contains an abundance of organic iron.

Within the next few years the absorption and assimilation of iron was studied by several experimenters, usually with particular reference to the question whether inorganic or synthetic organic compounds of iron are absorbed and assimilated, and especially whether such preparations contribute directly to the formation of hemoglobin. This question is, of course, extremely important, not only in connection with the therapeutic use of medicinal iron, but also in its bearing upon the iron requirements in health: for if inorganic iron could be utilized in the body in exactly the same way as the complex organic iron compounds of the food, it would follow that the iron of drinking water could replace that of food, and the supplying of food-iron would be a matter of indifference to a man whose drinking water supplied a few milligrams of iron per day. In opposition to this view Bunge held that little if any inorganic iron was assimilated under normal conditions, and that any effect of medicinal iron should be attributed to its action in protecting the food-iron from loss in digestion, principally by absorbing the sulphur liberated as sulphid through intestinal putrefaction.

Coppola,[b] whose work is quoted by Stockman[c], fed cocks on a diet containing no iron, having selected these birds because they have large blood corpuscles in which changes can be observed readily. The

[a] München. Med. Wchnschr., 37 (1890), pp. 654, 673.

[b] Sperimentale [Florence], 65 (1890), p. 227.

[c] Brit. Med. Jour., 1893, I, p. 881.

hemoglobin fell rapidly, but the red corpuscles were not diminished in number, although, as in chlorosis, there were many irregularly shaped, small, and pale ones among them. In one experiment the hemoglobin fell in seven days from 42 to 33 per cent. Coppola then added to the daily food 25 milligrams of lactate of iron; after five days the hemoglobin had risen to 65 per cent. He concluded that iron salts must be absorbed and go to form hemoglobin.

Kunkel [a] found in experiments upon dogs and mice that feeding iron salts increased the iron content of the liver, but pointed out that since the food was rich in hemoglobin the inorganic iron administered might have acted simply by improving the digestion and absorption of the food-iron. It has also been stated by Tartakowsky [b] in criticism of Kunkel's experiments that he failed to wash the livers free from blood, and that the blood content of these organs might fluctuate sufficiently to introduce very serious errors. Gottleib [c], recognizing the fact that iron might be absorbed and used by the body yet finally excreted with the feces, determined the intestinal elimination of iron in dogs before and after subcutaneous and intravenous injections of known amounts of iron salts. From the results obtained it was estimated that practically all of the injected iron was eliminated by the intestines. Gottleib further showed that bile contains only a minute quantity of iron, which is not appreciably increased by the administration of iron salts. This result was confirmed by Dastre [d] and Anselm [e], and later also by F. Voit.[f]

Tirmann [g] found that crystalline hemoglobin and hematin given by the mouth were absorbed and gave rise to an increase in the iron content of the urine, though about nine-tenths of the eliminated iron passed out through the intestine.

Marfori [h] prepared an iron-proteid compound showing reactions similar to Bunge's hematogen and containing 0.702 per cent of iron. In order to test the absorption of the iron in this form he kept a dog for six days upon milk alone, purging with Glauber salts at the same time; on the seventh day the dog fasted, on the eighth day he was fed with iron-proteid compound, after which no further food was given, and at the end of forty-eight hours after feeding the

---

[a] Arch. Physiol. [Pflüger], 50 (1891), p. 1.

[b] Arch. Physiol. [Pflüger], 101 (1904), p. 448.

[c] Ztschr. Physiol. Chem., 15 (1890–91), p. 371.

[d] Arch. Physiol. Norm. et Path., 5. ser., 3 (1891), No. 1. (Voit.)

[e] Ueber die Eisenausscheidung durch die Galle. Inaug. Diss., Univ. Dorpat, 1891.

[f] Ztschr. Biol., 29 (1893), p. 325.

[g] Pharm. Ztschr. Russ., 34, pp. 403, 433; abs. in Jour. Chem. Soc. [London], 1896, II, p. 487.

[h] Arch. Expt. Path. u. Pharmakol., 29 (1891), p. 212.

dog was killed, and the iron content of the entire gastro-intestinal tract was determined. Three such experiments were made. In the first and second 55.2 and 56.8 per cent of the iron fed appeared to have been absorbed, while in the third 10 per cent more iron was found in the digestive tract than had been fed.

Selensky[a] fed dogs upon rice and observed the effect upon the hemoglobin content of the blood. In one experiment the percentage of hemoglobin fell from 18.5 to 13.1 in nine days; in another, from 14.8 to 11.3 in six days, and on continuing the diet the anemia became more pronounced, and the dog died at the end of seventeen days on the rice diet. Here the number of red corpuscles was greatly decreased. On a mixed diet without meat there was a similar decrease of hemoglobin, but only a very slight diminution in the number of red corpuscles. According to Selensky, dogs can not live on rice diet. In fact, the dog thus fed in Selensky's experiment died sooner than the dog kept in absolute fasting by Falck. Later experiments by Tartakowsky, however, failed to confirm this result.

Moerner[b] found that the addition of iron salts to the food had no appreciable effect upon the proportions of inorganic and ethereal sulphates in the urine, and therefore concluded that the iron salts did not diminish intestinal putrefaction, but simply removed the hydrogen sulphid formed.

Voit[c] studied the metabolism of iron in dogs by direct observations of absorption and elimination in isolated sections of the small intestine. Opening the peritoneal cavity under narcosis he separated the desired section, removed the contents, closed the ends, and left the sac thus formed in its normal position after having reestablished the continuity of the remainder of the intestine by uniting the cut ends. By killing and examining animals which had been kept for some time after such an operation, Voit was able to compare the amount of iron eliminated through the intestinal wall with the amounts contained in food and feces, and thus to infer the extent to which the iron taken by the mouth was absorbed and returned to the intestine for elimination. In fasting, the daily elimination found for each square meter of intestinal surface was 6 milligrams in the feces and the same amount (per square meter of surface) in the isolated loop of intestine. On food poor in iron the feces contained in each of two cases 10 milligrams, the isolated loops 6 and 9 milligrams of iron per square meter of intestinal surface; while on food rich in iron the corresponding figures for two experiments were 43 and 78 milligrams in the feces, 8 and 6 milligrams in the

---

[a] Zur Lehre von dem Einflusse mancher Ernaehrungsbedingungen auf den Blutbestand. Quoted by Tartakowsky, loc. cit., p. 479.

[b] Ztschr. Physiol. Chem., 18 (1895), p. 13.

[c] Ztschr. Biol., 29 (1893), p. 325.

isolated portion of the intestine. Hence it appears that the iron eliminated in fasting or on food poor in iron came from the body through the intestinal wall, while the extra iron given with the food in the last two experiments passed through the alimentary canal without being absorbed to any appreciable extent. For a more direct test of the absorption of iron Voit injected in the isolated loops of the intestine known amounts of iron, (1) as liquor ferri albuminati, (2) as oxyhemoglobin, and (3) as iron citrate. On killing the animals five hours later the closed sections were found in the first and second experiments to contain slightly more iron than had been injected. The third experiment showed an appreciable absorption of iron, but the intestinal wall was much inflamed in this case. From these results Voit concluded that of the iron given medicinally or contained in an abundant diet only a small proportion is absorbed and that the iron which is thus absorbed and metabolized is eliminated almost entirely through the intestinal wall. Moreover, it should be noted that recent observations have shown elimination through the walls of the large as well as the small intestine.

Stockman, in his first paper upon the metabolism of iron,[a] although discussing mainly the therapeutics of chlorosis, undertook to solve the question of the absorption of inorganic iron. He reasoned as follows:

If inorganic iron preparations given hypodermically will cure chlorosis, there can in such cases be no possibility of the iron exerting its effect by the stimulation of the alimentary canal or by combining with hydrogen sulphid in the intestine.

If iron sulphid given by the mouth cures chlorosis, it must be through absorption of the iron, since ferrous sulphid has no stimulating effect and can not take up more sulphur.

If bismuth, manganese, etc., take up hydrogen sulphid as readily as iron, but are inert in chlorosis, a further indirect evidence of absorption of iron is obtained.

Stockman made experiments and observations upon hospital patients[b] (of which he cites nine cases), which appear to substantiate each of the three propositions, and thus to establish the fact that inorganic iron preparations cure chlorosis through being absorbed and utilized in the formation of hemoglobin.

After acute hemorrhage the iron of the blood is renewed from that of the food. This is sometimes the case in chlorosis, but according to Stockman the patients usually recover only when inorganic iron

---

[a] Brit. Med. Jour., 1893, I, p. 881.

[b] In addition to his own experiments Stockman cites a number of authorities for the cure of chlorosis or anemia by hypodermic injection of iron in various medicinal forms.

is given. On the other hand, inorganic iron given to healthy persons does not affect the number of red blood corpuscles or the amount of hemoglobin. It seems impossible to increase the number of corpuscles or the amount of hemoglobin above a certain fixed normal for the individual, which Stockman found to be rarely above 100 in men or 88 in women, on the scale of Gower's hemoglobimeter.

During the years 1894–1897 several investigators studied the absorption of different forms of iron by microchemical methods.[a] Suitable stains having been found for the identification of iron in the microscopic sections of tissue, it was possible by examination of the intestinal wall and the various organs and tissues of the body to follow the absorption, storage, and elimination of the iron given with the food. Macallum[b] investigated in this manner the absorption of inorganic salts of iron, iron albuminates, and the iron compound of the egg yolk, with results which he summarized essentially as follows:

Experiments on administration of inorganic compounds of iron to guinea pigs and other animals have resulted in showing that the intestinal mucosa absorbs these to an extent which varies with the nature of the compound and with the quantity given. When the dose is small, absorption occurs only in that part of the intestine adjacent to the pylorus and measuring only a few inches in length, yet when the quantity given at any one time is large, the absorption area may embrace the whole of the small intestine. In the former case the result appears to depend upon the complete precipitation as hydroxid of the iron of the salt unabsorbed, in the thoroughly mixed bile, chyme, and pancreatic juice; and in the latter case, the large amount of iron salt apparently first destroys the alkalinity of these fluids, the excess of the salt unaffected and remaining in solution then undergoing absorption.

The intestinal epithelial cells transfer the absorbed iron at once to the underlying elements when the quantity absorbed is small, but with a large amount of iron absorbed the epithelial cells are found to contain some of it.

Though some of the subepithelial leucocytes of the villi appear to carry part of the absorbed iron into the general blood circulation, probably the more important agent in the transference of the inorganic iron from the villi to the other parts of the body is the blood plasma.

A commercial albuminate and commercial "peptonate" of iron, when administered to guinea pigs, seem to stimulate the leucocytes to invade the epithelial layer of the intestinal villi.

Of the organic iron compounds of the "chromatin" class, that present in egg yolk (hematogen of Bunge) undergoes absorption in the intestine of the guinea pig and of Amblystoma, since the liver cells gave evidence of an organic iron compound derived from the egg yolk fed.

The mode of absorption of yolk chromatin is obscure, but the process appears in some way to be connected with the absorption of the fat with which the iron compound is so closely associated in the yolk.

---

[a] For a discussion of such methods see Quincke's "Eisentherapie" and the papers of Macallum (quoted beyond) and of Matzner, St. Petersburg Med. Woch., 1905, No. 26.

[b] Jour. Physiol., 16 (1894), p. 268.

Hochhaus and Quincke[a] and Hall[b] also demonstrated by microchemical reactions the absorbtion of medicinal preparations of iron.

Woltering[c] compared microchemically and by quantitative determination the amounts of iron in the livers of mice, rabbits, and dogs, fed with and without sulphate of iron, and reported an increase in the iron content of the liver and in the hemoglobin and red corpuscles of the blood as the result of feeding the iron salt.

Cloetta,[d] experimenting upon loops of the small intestine in the dog, found an absorption of 19 to 23 per cent of the iron introduced in the form of ferratin natr. sol. There was in increase in the iron content of the liver, but not in the hemoglobin content of the blood.

Gaule,[e] using principally microchemical methods, found no reaction for iron in the chyle under normal conditions; but a distinct reaction appeared in the lymph nodes, and extended to the spleen soon after the ingestion of iron salt in rabbits. This absorption of inorganic iron was followed by an increase in the number of red corpuscles and percentage of hemoglobin in the blood. Gaule held that the absorbed iron was carried to the spleen and there stored temporarily, and converted into more complex compounds, which are ultimately used in the synthesis of hemoglobin.

Further observations confirming the absorption of inorganic iron have been made by Hofmann,[f] Hönigmann,[g] Swirski,[h] Abderhalden,[i] Müller,[j] Landau,[k] Wolf,[l] and Tartakowski.[m]

In the meantime Kunkel and Egers studied especially the influence of iron salts upon the regeneration of blood after hemorrhage. Kunkel[n] kept two dogs on a limited milk diet, but gave one of them, in addition to the milk, 4.4 milligrams of iron per day in the form of albuminate. Each of the animals was bled every seven days, about one-third of the total blood being taken each time. The iron

---

[a] Arch. Expt. Path. u. Pharmakol., 37 (1896), p. 159.

[b] Arch. Anat. u. Physiol., 1896, p. 49.

[c] Ztschr. Physiol. Chem., 21 (1895), p. 186.

[d] Arch. Expt. Path. u. Pharmakol, 38 (1896), p. 161.

[e] Deut. Med. Wchnschr., 1896, pp. 289, 372; Ztschr. Biol., 35 (1897), p. 377.

[f] Arch. Path. Anat. u. Physiol. [Virchow], 151 (1898), p. 488; 160 (1900), p. 235.

[g] Arch. Path. Anat. u. Physiol. [Virchow], 152 (1898), p. 191.

[h] Arch. Physiol. [Pflüger], 74 (1899), p. 466.

[i] Ztschr. Biol., 39 (1900), p. 113.

[j] Arch. Path. Anat. u. Physiol. [Virchow], 164 (1901), p. 436.

[k] Ztschr. Klin. Med., 46 (1902), p. 223; abs. in. Jahrseber. Tier. Chem., 32 (1902), p. 697.

[l] Ann. Soc. Med. Chirurg. Liege, 5. ser., 42, p. 118; Jahresber. Tier. Chem., 33 (1904), p. 529.

[m] Arch. Physiol. [Pflüger], 100 (1903), p. 586; 101 (1904), p. 423.

[n] Arch. Physiol. [Pflüger], 61 (1895), p. 595.

in the drawn blood was determined and ascertained to be greater than the amount supplied by the milk, but less than the total iron received by the dog which was fed with albuminate. The experiment was continued seven weeks, at the end of which time the blood and organs of the dog which had been kept on milk alone were poorer in iron than those of the dog which had received the iron albuminate. Only one animal was fed in each way, and no determinations of hemoglobin are recorded. According to Egers [a] the regeneration of blood after severe losses (one-third of the estimated total) is very slow on food poor in iron, unless medicinal iron is also given, when the rate of regeneration becomes better, but not so good as on a diet supplying an abundance of food-iron alone. Even when the diet was rich in food-iron, however, Egers found that medicinal iron appeared to aid the regeneration of blood after hemorrhage.

The investigations mentioned having shown that inorganic iron is at least to some extent absorbed and carried to organs which take part in the production of hemoglobin, it became of especial importance to determine by long-continued feeding experiments whether the inorganic iron thus absorbed can take the place of food-iron in the production of hemoglobin under normal conditions.

This question was studied by Häusermann [b] in an extended series of experiments carried out in Bunge's laboratory. The general plan of these experiments was to feed young animals from the end of the normal suckling period upon food poor in iron, usually milk and rice. One half of the animals, however, received ferric chlorid in addition to this food. After the animals had been thus fed for one to three months and had usually doubled in weight they were killed and the amount of hemoglobin in the entire body was estimated; also, in the case of small animals, the total amount of iron. Experiments were carried out in this way upon 24 rats, 17 rabbits, and 14 dogs. The results are summarized as follows by Bunge: [c]

> The rats became highly anemic, for at the end of the experiment the percentage of hemoglobin was diminished to about half that of animals from the same litter which had received their normal food, namely meat, flies, yolk of egg, fruit, and vegetables. The rats which had taken ferric chlorid in addition to the milk and rice contained no more hemoglobin than those which had received milk and rice only. Moreover, the amount of iron was in each case the same. In one experiment alone, in which the addition of ferric chlorid was continued for three months, was the iron found to be double as much in the animals which had received it as in those which had only milk and rice. But here again the proportion of hemoglobin remained the same in both instances. We thus see that some iron is absorbed if small doses of iron are persisted in for a long time as well as if large amounts be suddenly administered. But

[a] Ztschr. Klin. Med., 32 (1897), p. 335.

[b] Ztschr. Physiol. Chem., 23 (1897), p. 555.

[c] Physiological and Pathological Chemistry, Philadelphia, 1902, 2 Eng. ed., p. 379.

this inorganic iron, when absorbed, is not utilized in the formation of hemoglobin to any appreciable extent, but remains unused in the tissues. Whether inorganic iron was absorbed in the experiments, which lasted only from one to two months, can not be decided; it is possible that some of it was absorbed and was again eliminated in the same degree. Certainly no storing up nor increase of iron could be detected in the whole organism.

The experiments on rabbits gave less decisive results: The average proportion of hemoglobin in the animals that received inorganic iron was somewhat higher than that in the animals which were fed on milk and rice only. But when the great individual differences between various animals are taken into consideration, too much importance must not be ascribed to this slight divergence. At any rate the amount of hemoglobin in the control animal, which received its normal diet—fresh green cabbage, bran, etc.—was nearly twice as high as in the animal which received the inorganic iron.

The experiments upon dogs were not attended with decisive results, as dogs are not suitable animals for these experiments, owing to the variation in individuals. Moreover, the growth of these animals after the period of lactation is at a much slower rate, and their appetite is so enormous that they might readily be able to assimilate sufficient hemoglobin even from a material so poor in iron as milk, while their appetite remained normal. Häusermann found the largest proportion of hemoglobin in a dog which had been fed exclusively upon milk. The animals which received ferric chlorid in addition to a milk diet certainly contained no more hemoglobin than animals from the same litter which were fed on meat and bones.

Abderhalden, following Häusermann, studied the subject even more exhaustively. His comparative analyses [a] showed that in rabbits and guinea pigs (as Bunge had previously found in dogs) the composition of milk ash and the ash of new-born animals was nearly the same except that the ash of the young animals was richer in iron than the milk ash, indicating that the animals are born with a store of iron, as Bunge had taught. In guinea pigs the difference in iron content between milk ash and body ash was smaller than in dogs or rabbits, which also agrees with Bunge's view that guinea pigs have less need of a store of iron since they begin to eat food rich in iron (leaves of vegetables, etc.) from birth, and do not depend exclusively upon milk during the suckling period. The question of the absorption and utilization of different forms of iron was then investigated by Abderhalden in extended series of experiments upon several species of animals.[b] In order to ascertain whether and to what extent sulphids normally exist in the alimentary canal—a question of special importance in connection with Bunge's view of the mode of action of inorganic iron—Abderhalden killed and examined rats, mice, cats, dogs, guinea pigs, and rabbits in the following way: Immediately upon killing the animal the abdomen was opened and the intestinal tract from the esophagus to the rectum was ligated in sections. The contents of each section were then removed and tested

[a] Ztschr. Physiol. Chem., 26 (1898), p. 436; 27 (1899), p. 356.

[b] Ztschr. Biol., 39 (1900), pp. 113, 193, 483.

qualitatively for sulphids by heating in a small beaker with a small amount of hydrochloric acid and exposing over the heated liquid a few drops of lead acetate solution. Hydrogen sulphid was obtained from the contents of the large intestine but not from those of the small intestine nor of the stomach. Hence, if inorganic iron acts by improving the absorption of food-iron, it must do so in some other way than by simply preventing its precipitation as sulphid, since this would not occur in the small intestine where the principal absorption of iron takes place. The next step in the investigation was to study by micro-chemical methods the absorption of inorganic iron, its behavior in the body, and its elimination. Experiments were made upon 49 rats from 7 litters, 14 guinea pigs from 6 litters, 12 rabbits from 2 litters, 10 dogs from 3 litters, and 6 cats from 2 litters.

Part of the animals from each litter were fed upon a diet poor in iron, composed of white bread, milk, and a mixture of rice and milk cooked to a thick paste. The other animals received the same food with the addition of known amounts of iron chlorid. The amounts of iron fed per day were: To rats, 0.4–0.5 milligram; to rabbits, 4 milligrams; to guinea pigs, 2–3 milligrams; to dogs, 3.5–4 milligrams, and to cats, 4 milligrams. These amounts are much smaller than have generally been given by other investigators, but are governed by the amounts used therapeutically in the case of man and by a consideration of the relative lengths of digestive tract of the different species.

Micro-chemical examinations indicated that the inorganic iron thus given was absorbed, deposited mainly in the liver and spleen, and finally eliminated through the walls of both small and large intestines.

From all of these experiments Abderhalden concluded that the complicated iron compounds of the normal food, the iron in the form of hemoglobin and hematin, and the inorganic iron were all absorbed in the same general way, stored in the same organs, and eliminated by the same paths.

In studying the utilization by the body of the different forms of iron, Abderhalden used the method recommended by Bunge and followed by Häusermann. Animals were fed from the end of the suckling period, or in the case of guinea pigs from birth. on food poor in iron, and each litter was divided into two lots. one of which was given inorganic iron in addition. After a sufficient time the animals were killed and the total hemoglobin in the body of each was estimated. Experiments with inorganic iron were made upon 48 rats, 44 rabbits. 14 guinea pigs, 17 cats. and 11 dogs; with hemoglobin upon 43 rats, and with hematin upon 28 rats. These experiments led to the following conclusions:

The small amount of iron contained in the normal food is sufficient

for hemoglobin formation. The animals fed with food poor in iron plus an addition of inorganic iron were in the long run unable to produce as much hemoglobin as those receiving normal food. Iron of hemoglobin and hematin is assimilated and (at least when other forms of food-iron are not abundant) probably contributes to the production of hemoglobin in the body.

In these experiments Abderhalden had noticed some facts which indicated that the favorable influence of inorganic iron upon metabolism and blood formation was greater on a diet rich in food-iron than when the amount of food-iron was kept small. In order to test this, experiments were made with 66 rats, 10 rabbits, and 14 guinea pigs, in the manner already described, but with diets arranged to bring out this particular point. These experiments led to the conclusion that the greater the quantity of food-iron present the greater the influence of the inorganic iron upon the hemoglobin formation.

Abderhalden's experiments showed that the production of hemoglobin was not stimulated indefinitely by inorganic iron, but only for a short time. The same has been found clinically, and indicates that the action is simply due to stimulation without the inorganic iron actually going to form hemoglobin.

Corresponding experiments upon rats with hematin indicated that an addition of complicated organic compounds of iron to a diet already sufficient and containing an abundance of normal food-iron does not cause any increase of hemoglobin production above the normal. Such organic compounds may however be very efficient in cases in which the food is poor in iron or in which the amount of food taken is deficient.

The principal conclusions drawn by Abderhalden from the results of these exhaustive investigations are essentially as follows:

> Inorganic iron given by the mouth, in small doses, is absorbed, as is also iron given in the form of hemoglobin and hematin. The complex iron compounds of the normal food are absorbed, stored, and eliminated—in part at least—by the same organs as the inorganic iron.
>
> Animals are able to assimilate much more iron from a normal diet than from a diet poor in food-iron to which inorganic iron, hemoglobin, or hematin is added. The more food-iron available the more is the prduction of hemoglobin stimulated by the administration of iron salts. Inorganic iron is not used as material for the production of hemoglobin.

Some of Abderhalden's conclusions have been contested by Jacquet [a] and also by Tartakowsky,[b] who cites in support of his own views a large number of observations made mainly upon dogs by micro-chemical methods. According to Tartakowsky, milk and rice are so poor

[a] For Jacquet's criticisms and Abderhalden's replies see Ther. Monatsh., 15 (1901), pp. 339, 473, 474, and 635.

[b] Arch. Physiol. [Pflüger], 100 (1903), p. 584; 101 (1904), p. 423.

in iron that the amount supplied by a diet of these is not sufficient for the purpose of the growing organism so that the blood becomes progressively poorer in iron, and after a time the animal ceases to grow. Such animals are found on examination to contain less than the normal amount of iron in the liver and spleen and the micro-chemical reactions also show a lack of iron in the organs and tissues.

The addition of inorganic iron to the milk-rice diet supplies the deficiency, the blood regains its normal iron content, and the animal quickly begins to grow again. The inorganic iron, therefore, is held to exert the same action as the complicated organic compounds of iron in the natural food. From this Tartakowsky reasons that the medicinal iron, like the food-iron, is not only absorbed but assimilated; that is, it serves as material for the production of hemoglobin and is stored as reserve iron in the organs. Tartakowsky further insists that Abderhalden's experiments should also be interpreted in this way, since in many cases the animals which received inorganic iron in addition to their food formed more hemoglobin than the control animals.

Tartakowsky does not accept the view that inorganic iron stimulates blood regeneration after hemorrhage in animals on food rich in iron, and believes that the beneficial effect in cases in which the amount of iron supplied by the food is small is not due to stimulation, but to the direct utilization of the inorganic iron for hemoglobin formation in exactly the same way in which the iron of the food is utilized. Thus Tartakowsky cites the results of his own experiments to show that healthy animals on normal food (dogs on meat and rabbits on green fodder) are not made anemic even by repeated bleeding, no stimulus other than the loss of blood being required to bring about a rapid regeneration of hemoglobin so long as the food supplies a normal amount of iron. If on the other hand the food is poor in iron, then bleeding causes a long-continued impoverishment of the blood which, however, is quickly made good by the administration of medicinal iron without change in the diet.

In view of these facts, it is claimed that the now common explanation of the stimulating effect of iron is not applicable to healthy animals, although it may account for the good effect of iron salts in cases of chlorosis in which a functional weakness of the blood-forming organs exists, though Tartakowsky thinks it more probable that even in such cases the inorganic iron acts no differently from the food-iron and that the increased blood formation is due to the "mass action" of the increased amount of iron brought into the body.

While Tartakowsky supports his contention by a considerable number of observations, it should be noted that most of these are micro-chemical and therefore only qualitative. For this reason they do not appear to be adequate to overthrow the most important con-

clusion drawn from the work of Häusermann and Abderhalden, namely, that inorganic iron, if used at all by the body as material for the production of hemoglobin, is less efficient (as shown by quantitative determinations) than the iron compounds of the normal food. In fact, Tartakowsky's own experiments emphasize the importance of the food-iron.

While it can not yet be stated positively that inorganic iron is or is not used by the animal body as material for the production of hemoglobin, medical opinion appears to support the conclusion reached by Abderhalden, that hemoglobin is derived essentially from the organic iron compounds of the food, while inorganic iron acts mainly if not entirely as a stimulus. This view is strongly supported by von Noorden [a] in a treatise on chlorosis in a recent encyclopedic work. Ehrlich and Lazarus [b] writing on anemia in the same work state:

> It is not very probable that the (medicinal) iron stored by the liver and spleen is directly employed in the formation of hemoglobin; on the contrary, the assumption first suggested by von Noorden, seems much more plausible, namely, that the iron exercises a direct irritative action on the function of the blood-making organs.

Before attempting to summarize the results of investigations upon the absorption and metabolism of iron, it is desirable to review some of the more important relations of iron to the general metabolism.

THE RELATION OF IRON TO GENERAL METABOLISM.

It has long been known that the general metabolism of the animal body is largely dependent upon oxidation, and that iron is an essential constituent of the oxygen-carrying hemoglobin of the blood. When Bunge showed in 1884 that in egg yolk the iron is firmly combined with the phosphorized proteid to which he gave the name "hematogen," he gave as the elementary composition of hematogen: Carbon, 42.11 per cent; hydrogen, 6.08 per cent; nitrogen, 14.73 per cent; sulphur, 0.55 per cent; phosphorus, 5.19 per cent; iron, 0.29 per cent; oxygen, 31.05 per cent. The general composition of this compound therefore approaches closely to that of the typical nucleoproteids, and numerous observations have indicated that both phosphorus in the form of nucleoproteids and iron in some firmly bound organic combination occur, especially in those cells in which metabolism appears to be most active, such as the secreting cells and the leucocytes. Macallum [c] in 1891 described a method by which the presence of

[a] Diseases of the Blood; Nothnagel's Encyclopedia of Practical Medicine. Philadelphia, 1905, p. 339.

[b] Loc. cit., p. 17.

[c] Proc. Roy. Soc. [London], 50 (1891–92), p. 277.

iron may be demonstrated micro-chemically in the chromatin of animal and vegetable cells, and gave results indicating that iron is always a constituent of this substance. At about the same time he[a] also pointed out certain relations between the chromatin of the pancreatic cell and the formative process resulting in the production of zymogen. The results of extensive studies in the same direction, published by Macallum[b] a few years later indicate that iron is an essential constituent of all parts of the chromatin of animal cells and the amount of iron corresponds to the amount of chromatin present. Similar results were obtained with the higher vegetable organisms also. The importance of iron to the characteristic processes of secreting cells was confirmed and explained by the view that the zymogen contains iron and that its antecedent, the prozymogen, is the iron-holding constituent of the cytoplasm of the outer zone. From the results of his numerous observations Macallum drew the following conclusions regarding the relations of iron compounds to the general processes of metabolism:

> The facts described appear to indicate that a substance in which iron is firmly held is a constant constituent of the nucleus, animal and vegetable, of the cytoplasm of nonnucleated organisms and those possessed of apparently rudimentary nuclei, and that, further, a similar iron-containing substance obtains in the cytoplasm of ferment-forming cells. This substance, to which cytologists apply the term chromatin, can not, on theoretical grounds, be regarded as constant in its molecular structure, even in the same organism, and its most marked characteristic, apart from the iron in its composition, is the occurrence in it of nuclein or nucleinic acid.
>
> Beyond the fact that the iron is firmly held, it is difficult to say how it is disposed in the molecular structure of the nuclein or nucleinic acid. It is, possibly, united directly to the carbon of the latter. The acid alcohols liberate it as a ferric salt, but this fact can not be held to indicate that it is combined in the nuclei or nucleinic acid in a ferric state, since, from solutions of potassium ferrocyanid, in which the iron is contained in a ferrous state, acids liberate the iron in a ferric condition, as evidenced by the formation of ferric ferrocyanid or Prussian blue.
>
> It is also difficult to say whether there is, in the way in which the iron is held in the animal cell, anything different from that obtaining in the vegetable organism. I have, as a rule, found it easier in the case of the vegetable cell than in that of the animal cell to liberate the iron with ammonium hydrogen sulphid; but upon this no conclusion may be founded, since the same reagent liberates the iron of free hematin readily, while it does not affect the iron of hematin in hemoglobin, and it is possible that in the animal cell the proteid molecules attached to the iron-containing nuclein or nucleinic acid may more greatly affect the activity of the reagent than those of the vegetable cell are capable of doing. Since, on the other hand, hemoglobin, which as I have pointed out, is derived, in Amblystoma, from chromatin, occurs in a large number of animal forms, but is present in no vegetable organisms, it would appear to fol-

---

[a] Trans. Canad. Inst., 1 (1891), pt. 2, p. 247.

[b] Quart. Jour. Micros. Sci. [London], 38 (1896), p. 175.

low that the iron is combined in animal chromatin in a way unlike that in which it is held in the vegetable cell.

The apparently universal occurrence of such iron compounds renders intelligible the fate of the iron salts absorbed by plants from the soil and of the iron compounds found by Rankin and Molisch to be necessary for the growth of *Aspergillus niger*. Chromatin, to the formation of which the iron absorbed contributes, is, as the results of cytological investigations show, a substance of primary importance to the cell, and a diminution in or a cessation of the supply of iron to the vegetable organism, which produces the condition known as chlorosis, instead of affecting only the formation of its chlorophyll, as generally supposed, strikes at its very life.

The conditions known as anemia and chlorosis in the higher vertebrates have been hitherto explained as caused by a diminished production of hemoglobin directly from organic or inorganic iron compounds absorbed by the intestine from the food matters, but they must now be referred to a deficient supply of the primary iron-containing compound—chromatin—not only in the hematoblasts, but in all the cells of the body. The consequently lessened proliferation of cell and tissue would explain the hypoplasia of the imperfectly developed vascular system observed by Virchow in chlorotic human subjects.

Accepting this explanation of the nature of chlorosis, one may infer that this condition is not limited to animal organisms in which hemoglobin is found, although its occurrence in others may be difficult to detect because of the total absence of this pigment. From this point of view animal chlorosis is fundamentally similar to the chlorosis of the vegetable kingdom.

The oxygen-carrying property of hemoglobin and of hematin is generally attributed to the iron present in these, because when hematin is deprived of its iron, the resulting compound, whether hematoporphyrin or bilirubin, manifests no affinity for oxygen. The proof may not be quite conclusive, for we can not be certain that either compound represents the unchanged remainder of the hematin less its iron, but assuming that it is correct, it follows, as I have pointed out in my previous communication, that the antecedent of hemoglobin, chromatin, has the capacity of absorbing and retaining oxygen, and that one may attribute the processes grouped under the term "vital" to an alternation of the conditions of oxidation and reduction in the iron-holding nuclear constituent.

At about the same time, Barker[a] noted the occurrence of iron in leucocytes in such stable organic combination as to escape detection by the ordinary staining reagents.

Vay[b] studied the variations in the amounts of iron in the liver, especially the iron present as Schmedeberg's ferratin. In the livers of lower animals the percentage of ferratin varied from 0.15 to 0.30 per cent, corresponding to 0.01 to 0.018 per cent of iron in the fresh substance. In man the iron content of the liver was slightly lower and was believed to run parallel with the condition of nutrition.

Spitzer, in 1897,[c] pointed out the relation between the oxidative powers of different organs and the nucleo-proteids which they contain. The nucleo-proteids of the liver, spleen, and other organs were

---

[a] Johns Hopkins Hosp. Bul., 1894, No. 42, p. 93.

[b] Ztschr. Physiol. Chem., 20 (1895), p. 377.

[c] Arch. Physiol. [Pflüger], 67 (1897), p. 615.

analyzed and in every case iron was found to be an essential constituent.

That iron is a normal constituent of the nucleo-proteids is generally accepted. In his recent work on proteids Mann [a] states:

> Iron is contained in most if not all nucleo-proteids, and if we except the iron present in the hemoglobin, the main bulk of the remaining iron concerned in metabolism is contained in the nucleo-proteids.

Although unable to demonstrate the exact mode of action of the iron-holding radicals in the nucleo-proteids, Spitzer held that they were intimately connected with the oxidation processes in both plant and animal metabolism. Spitzer's conclusion therefore agrees entirely with that of Macallum, though reached by different methods and apparently with no knowledge of Macallum's work. Moreover, Brodie [b] also found iron in each of several proteids from the spleen.

In connection with an extended study of the physiology of the salmon in fresh water, Grieg [c] investigated the exchange of iron between muscle and ovaries. The object of this investigation was to determine whether the iron of the paranuclein of the ovary increases with the growth of that organ, and if so, whether the iron, like the fats, proteids, and phosphorus, is derived from the muscles.

The amounts of iron in the muscles, liver, and ovaries of two fish leaving the sea in May and of two fish taken from the upper reaches of the river in October were determined. Since it had been found that the salmon takes no food while in fresh water, any increase in the iron content of an organ could be accounted for only as due to transference of iron from some other part of the body.

TABLE 1.—*Iron in organs of fish taken at different seasons.*

When taken.	Amount of iron in—		
	Ovaries.	Muscles.	Liver.
	Gram.	*Gram.*	*Gram.*
Fish taken in May	0.0054	0.108	0.0248
Fish taken in October	.0568	.0763	.02489

The ovaries, he points out, gained 0.0514 gram of iron, of which 0.0317 gram came from the muscles; the remainder apparently did not come from the liver, and therefore probably came from the hemoglobin of the blood.

Thus, while Bunge showed that the precursor of hemoglobin in the chick is the iron-holding proteid of the egg, Grieg's results indicate that the process is a reversible one and that the iron required for the

[a] Chemistry of the Proteids. London and New York, 1906, p. 450.

[b] Proc. Roy. Soc. Edinb., 24 (1902), p. 21; abs. in Jour. Chem. Soc. [London], 1905, II, p. 339.

[c] Jour. Physiol., 22 (1898), p. 355.

synthesis of the paranucleo-proteid of egg can be supplied by hemoglobin. Here the metabolism of iron is intimately connected with that of phosphorus and with the chemical processes involved in reproduction and development.

GENERAL DEDUCTIONS REGARDING THE METABOLISM OF IRON.

A summary of the various investigations which have been cited leads to some general deductions, which follow:

Iron is an essential constituent of the cells and tissues most directly concerned with the processes of oxidation, secretion, reproduction, and development, and stands therefore in fundamental relation to metabolism and nutrition in the broadest sense. The iron-holding constituents of the body which are thus especially connected with the metabolic processes are of very complex constitution, belonging mainly to the group of compound proteids, and the iron in them is held in firm organic combination. The normal materials for the production of these substances in the body are the similar iron-proteid compounds of the food.

The iron of the food is absorbed mainly from the duodenum, but also to some extent from the jejunum, enters the circulation by way of the lymph tract, and is deposited mainly in the liver, spleen, and bone marrow. Its final elimination takes place mainly through the walls of the intestines, probably especially in the colon.

Both inorganic and synthetically prepared organic forms of iron are absorbed in the same way, stored in the same organs, and eliminated by the same paths as the iron derived from the food. These medicinal forms of iron often promote the formation of hemoglobin and red blood corpuscles.

Whether medicinal iron actually serves as material for the production of hemoglobin is not positively known, but we have what appears to be conclusive evidence that food-iron is assimilated to much better advantage than inorganic or synthetic forms, and that even when medicinal iron increases the production of hemoglobin its action is more beneficial in proportion as the food-iron is more abundant.

The net result of the numerous investigations of the past thirty years is to emphasize strongly the importance of the food-iron in nutrition.

IRON REQUIREMENTS OF THE HUMAN ORGANISM.

RESULTS OF PREVIOUS INVESTIGATIONS.

Most of the early work upon the amounts of iron consumed and eliminated gave results much too high, owing to the use of faulty methods of analysis, and experiments upon the iron requirements of man which seem reliable are not numerous.

Lehmann, Müller, Munk, Senator, and Zuntz[a] published in 1893 an extended investigation of the metabolism of the professional fasters Cetti and Breithaupt. Cetti fasted ten days, during which his weight decreased from 57 kilograms to 50 kilograms, and there was also a decrease in the number of corpuscles and the hemoglobin content of the blood. The feces eliminated during the ten days contained 73 milligrams of iron, or 7.3 milligrams per day. Breithaupt fasted six days and lost 3.5 kilograms in weight. The number of red corpuscles per cubic centimeter of blood remained practically unchanged, and the hemoglobin content of the blood increased. The feces contained 46 milligrams of iron, or 7.7 milligrams per day.

Stockman,[b] in 1895, by actual determinations of iron in the ordinary mixed diet used at the Royal Infirmary, Edinburgh, and in his own mixed diet, found from 6 to 11 milligrams in the daily food of healthy persons with normal appetite; while the food consumed by four chlorotic girls with poor appetite contained only 1.3 to 3.2 milligrams of iron per day. Stockman believed that a considerable part of the iron of the food was not absorbed, and that the amount actually metabolized and eliminated from the body was less under normal conditions than in fasting, and was probably well under 6 milligrams per day. The small amount of iron absorbed from an ordinary dietary is held by Stockman to afford sufficient evidence of the necessity for a store of reserve iron within the body, and in discussing this subject in connection with the treatment of anemia he[c] points out that under normal conditions the liver and spleen store up a certain amount of iron, which is available for the physiological needs of the organism, and which can be drawn on at once when there is a sudden demand for the rapid formation of red blood corpuscles, as, for example, after hemorrhage. This is shown by the observations that all healthy livers contain considerable iron (apart from that due to hemoglobin) and that after hemorrhage in man or animals, or after feeding animals on a diet poor in iron, much less than the usual quantity of iron is found in the liver. Thus, the reserve supply of iron in the liver and spleen maintains the iron balance of the blood and enables it to make good very readily small bleedings or other occasional demands upon it. Thus, healthy women do not become anemic from menstrual loss, while those who are already anemic, and in consequence have no such reserve of iron, suffer markedly.

In 1897 Stockman and Grieg[d] reported four experiments in which the income and outgo of iron were determined. The subject of one

---

[a] Arch. Path. Anat. u. Physiol. [Virchow], 131 (1893), Sup.

[b] Jour. Physiol., 18 (1895), p. 484.

[c] Brit. Med. Jour., 1896, I, p. 1077.

[d] Jour. Physiol., 21 (1897), p. 55.

experiment was chlorotic and had poor appetite and digestion. The results of the experiments upon normal subjects were as follows:

TABLE 2.—*Results of Stockman's experiments on metabolism of iron—Quantities per day.*

Experiment No.	Subject.	Food consumed.	Iron in food.	Iron in feces.	Iron in urine.	Gain (+) or loss (−).
			Mgs.	*Mgs.*	*Mgs.*	*Mgs.*
1	Man 20 years old..	Minced collops, 240 grams; biscuit, 200 grams; oatmeal, 80 grams; rice, 30 grams; butter, 30 grams; sugar, 40 grams; milk, 1,000 cubic centimeters; tea, salt, and water.	6.2	5.07	1.27	−0.14
2	Man 35 years old..	Same as in experiment No. 1 ...	6.2	8.10	1.23	−3.13
3	Man 20 years old..	Same diet, but different samples of food.	5.6	10.87	.67	−5.94

It will be seen that the results of these experiments do not substantiate Stockman's estimate that the iron requirement of the body is less than 6 milligrams per day. In the above experiments very digestible foods were used, so that the food-iron was probably quite well absorbed. In only one of the three cases, however, was the iron of the food (in this case 6.2 milligrams) approximately sufficient to maintain equilibrium. In the other two experiments with similar diet the outgo of iron was in one case 50 per cent, in the other 100 per cent in excess of the income. The average daily elimination for the three experiments was 9.07 milligrams.

It is important to recognize that Stockman's balance experiments show greater amounts of iron metabolized than he had estimated from his food analyses; for his statement that 6 milligrams of iron per day is sufficient for the requirements of the body has been quite widely quoted.

Von Wendt[a] has recently published the results of six metabolism experiments covering thirty-five days, in which the income and outgo of nitrogen, sulphur, phosphorus, iron, calcium, magnesium, and chlorin were determined. In the first four experiments the food consisted of sago, sugar, and butter. It furnished about 1 gram of nitrogen and from about 1,500 to 3,000 calories per day. In the first period of the fifth experiment (5a) the daily diet was 500 grams bread, 170 grams butter, 70 grams sugar, and 350 to 440 grams coagulated white of egg. It furnished approximately 3,200 calories, or 45 calories per kilogram of body weight per day. During the following period (5b) the subject took daily 200 grams butter, 150 grams sugar, 400 to 470 grams egg white, the whole furnishing 2,400 calories, or 33 calories per kilogram per day. The food of the sixth experiment contained a large amount of meat and was estimated to

[a] Skand. Arch. Physiol., 17 (1905), p. 211.

contain 28 milligrams of iron per day, which is so much in excess of the probable normal requirements as to make the results of no interest for the present purpose.

Omitting all days in which the balance was disturbed by the ingestion of inorganic iron for special experimental purposes, the income and outgo of iron, calcium, magnesium, phosphorus, and nitrogen are given in Table 3. Experiments 1, 4, and 5b covered two days each; experiments 2, 3, and 5a 1 three days each; and experiment 5a 2 four days. In some cases, as noted above, the experiments were of longer duration, but the balance of mineral constituents was disturbed by the addition of mineral salts to the diet.

Table 3.—*Summary of results of experiments by von Wendt on metabolism of mineral constituents—Quantities per day.*

Element.	In food.	In feces.	In urine.	Gain (+) or loss (−).
	Grams.	*Grams.*	*Grams.*	*Grams.*
Experiment No. 1:				
Iron	0.010	0.008	[a] 0.001	+0.001
Calcium	.043	.156	.030	− .143
Magnesium	.014	.015	.039	− .040
Phosphorus	.128	.099	.764	− .735
Nitrogen	1.450	.390	9.250	−8.190
Experiment No. 2:				
Iron	.006	.010	[a] .001	− .005
Calcium	.032	.240	.026	− .234
Magnesium	.011	.040	.026	− .055
Phosphorus	.085	.149	.871	− .935
Nitrogen	.930	.570	10.110	−9.750
Experiment No. 3:				
Iron	.016	.013	[a] .001	+ .002
Calcium	.921	.513	.069	+ .339
Magnesium	.013	.020	.046	− .053
Phosphorus	.808	.242	.889	− .323
Nitrogen	1.420	.430	8.310	−7.320
Experiment No. 4:				
Iron	.008	.008	[a] .001	− .001
Calcium	.917	.413	.121	+ .383
Magnesium	.012	.028	.047	− .063
Phosphorus	.786	.187	.992	− .393
Nitrogen	1.180	.340	9.780	−8.940
Experiment No. 5a 1:				
Iron	.017	.041	[a] .001	− .025
Calcium	.274	.692	.109	− .527
Magnesium	.213	.136	.071	+ .006
Phosphorus	.578	.425	.620	− .467
Nitrogen	16.830	1.190	15.510	+ .130
Experiment No. 5a 2: [b]				
Iron	.016	.015	[a] .001	± .000
Calcium	.483	.328	.158	− .003
Magnesium	.203	.096	.098	+ .009
Phosphorus	.740	.213	.590	− .063
Nitrogen	15.820	.980	14.370	+ .470
Experiment No. 5b:				
Iron	.007	.015	[a] .001	− .009
Calcium	.166	.249	.141	− .224
Magnesium	.078	.089	.080	− .091
Phosphorus	.101	.166	.432	− .497
Nitrogen	9.450	.930	13.790	−5.270

[a] From the results of a number of determinations made in advance, von Wendt assumed that the urinary elimination of iron would average 1 milligram per day in each experiment. The actual figures found for iron in urine varied from 1.7 milligrams to an amount too small for satisfactory determination, but estimated at about 0.2 milligram per day.

[b] At the beginning of the period designated 5a 2 the subject took 3 grams of dicalcium phosphate in addition to his food.

Von Wendt considers the figures given by Stockman and Grieg for iron in food too low, since in his experiments especially designed to have food poor in ash he always found at least 5 milligrams of iron

in the daily diet and usually (as will be seen from the above table) from 6 to 17 milligrams. He estimates that an average mixed diet will contain from 20 to 30 milligrams of iron, but agrees with Stockman that usually very little iron is actually absorbed. The reason assigned by von Wendt for the belief that little iron is assimilated is the observation that sudden changes in the amount of iron taken with the food are quickly followed by corresponding changes in the iron content of the feces. This is held to indicate that most of the iron taken by the mouth, either in a liberal mixed diet or as medicinal iron, passes through the alimentary canal unabsorbed, only a small amount being needed by the body, because (according to von Wendt) the "internal circulation" is very highly developed with respect to iron, so that in conditions of normal nutrition, when there is equilibrium of all the important elements, the iron from the compounds broken down in the body is used again for the synthesis of the necessary iron-holding substances instead of being eliminated after having once been katabolized. In this view the large loss of iron in experiment 5a 1 is explained as due to the disturbance of the internal circulation shown by the large loss of calcium, and it is pointed out that the loss of iron stopped at once when 3 grams of dicalcium phosphate were ingested with no appreciable change in the kind or amount of food consumed. Von Wendt concludes that at least under some conditions a large loss of calcium so disturbs the internal circulation as to cause a simultaneous loss of iron, and suggests as a possible explanation that the loss of calcium may imply an impoverishment of the bone marrow, and therefore an interference with the resynthesis of hemoglobin from the metabolic iron.

PLAN AND DATA OF THE PRESENT INVESTIGATION.

As a part of the present study of iron in relation to human nutrition, three metabolism experiments were carried out with special reference to the determination of the iron requirement. The subject was a healthy man engaged in laboratory work. The food taken in each experiment was decided upon in advance and was identical for each day of the experiment. In order to establish, if possible, the minimum quantity of iron which would suffice for maintenance, while at the same time using food materials to which the subject was accustomed (as constituents of his usual mixed diet), the amounts of food were purposely made small. Since the determination of iron in food materials is attended with many possibilities of error, extremely simple dietaries were adopted in order to reduce the number of iron determinations required, and thus minimize the danger of accidents in the preparation and analysis of the samples.

The bread used in all three experiments was one of the common brands of biscuit or "soda crackers" sold in small sealed packages. The contents of several packages were mixed and sampled and portions weighed out for each day's dietary in advance.

In the first experiment milk formed a part of the diet. It was obtained in sealed quart bottles from one of the large dealers in New York City and was doubtless from the mixed product of many cows. At each meal a fresh bottle was opened, the contents thoroughly mixed, the specific gravity determined, and portions withdrawn at once for consumption and analysis. Since the specific gravity was found to be practically uniform, indicating that all the milk was of the same general quality, composite samples were prepared for analysis by mixing equal amounts from each bottle used.

Coagulated white of egg was used in the second experiment. This was obtained from eggs which had been kept in boiling water for about thirty minutes. The coagulated white of each egg was carefully removed and freed as thoroughly as possible from all traces of yolk or shell. Any dark specks noticed in the body of the white were also removed. The coagulated whites were then mixed in glass-stoppered bottles and portions were weighed for analysis and for each day's dietary.

In all operations especial care was exercised to avoid touching any cf the food materials with utensils of any kind containing iron. The spatulas, forceps, etc., used were of silver and nickel, the vessels of platinum, glass, or glazed porcelain, thoroughly cleansed immediately before use.

METHODS OF ANALYSIS.

For the determination of moisture, fat, and ash the methods of the Association of Official Agricultural Chemists were used.[a] Nitrogen was determined by the Dyer modification of the Kjeldahl method, which has been found by repeated trials in this laboratory[b] to give slightly more accurate results than those obtained by following the exact directions of the official methods. Protein was estimated in all cases by multiplying the amounts or percentages of nitrogen by the factor 6.25. Phosphorus was determined by precipitating first as ammonium phosphomolybdate and finally as magnesium ammonium phosphate, organic matter having been destroyed before the first precipitation either by boiling with sulphuric and nitric acids, by burning with sodium carbonate using nitrate if necessary to facilitate the oxidation, or in the case of feces, of which the ash was porous and

[a] U. S. Dept. Agr., Bureau of Chemistry Bul. 46.

[b] Jour. Amer. Chem. Soc., 26 (1904), pp. 367, 1469.

alkaline, by simple ignition. Calcium and magnesium were determined by the usual gravimetric methods[a] in the ash of foods and feces, and in the urine, both with and without previous boiling with sulphuric and nitric acids to destroy organic matter.

Determination of iron was accomplished by burning the material in platinum dishes, extracting, if necessary, with hydrochloric acid to facilitate the access of air to the last portions of carbon, dissolving the ash in a small amount of hydrochloric acid, evaporating with excess of potassium permanganate to insure complete oxidation of any organic matter which might have escaped combustion, and, finally, determining the iron by the Zimmermann-Reinhardt method, using a very dilute standard solution of permanganate for the titration. Special precautions were taken to guard against volatilization of iron as ferric chlorid during the ignition of the sample, or, what is more likely to occur, contamination with iron from utensils or from the dust of the laboratory. The very small amount of iron in the reagents used was determined and allowed for in the calculation of each analysis, together with the amount of the dilute standard permanganate solution required to give a perceptible end-point in the titration. The possibility of error through the presence of small amounts of platinum from the dishes used in burning the samples was also recognized and guarded against. The Zimmermann-Reinhardt method for the reduction and titration of iron in presence of hydrochloric acid, while requiring considerable care and some experience in manipulation, has been used successfully for several years in general work in this laboratory, and was considered to be the most satisfactory process available for the determination of the small amounts of iron with which it was necessary to deal in this work.

COMPOSITION OF FOOD MATERIALS.

The three food materials used in these experiments yielded on analysis, by the methods above outlined, the following results:

TABLE 4.—*Composition of food materials.*

Lab. No.	Food.	Water.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Total ash.	Iron.	Calcium oxid.	Magnesium oxid.	Phosphorus.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
701	Crackers......	3.55	1.56	9.75	9.95	75.33	1.42	0.00155	0.0282	0.0176	0.0892
702	Milk..........	87.04	.517	3.23	4.11	4.88	.74	.000228	.1739	.0173	.0941
703	Egg white....	86.70	1.78	11.13	.27	....	....	.00014	.0104	.0170	.0110

GENERAL DESCRIPTION OF EXPERIMENTS.

In the first experiment the kinds and amounts of food taken were the same as had been used in previous studies with the same subject, and were known to be somewhat too small for the maintenance of

[a] Hoppe-Seyler and Thierfelder, Chemische Analyse (7th ed.), 1903.

nitrogen equilibrium, but just about sufficient to maintain the balance of income and outgo of phosphorus. In spite of the simplicity of the diet it had been found to be entirely agreeable to the subject, having been eaten with good appetite and readily digested even when continued for several days without variation. Since the subject was in perfect health and the diet furnished no excess of organic nutrients, and yet contained a liberal allowance of calcium and of phosphates, it was thought that the conditions would be very favorable to the iron metabolism and that the amount of iron eliminated during this experiment would approximate the normal minimum for this subject.

The second experiment followed the first without intermission. The diet was planned to furnish approximately the same amounts of protein and of total fuel value as in the first experiment, but considerably smaller quantities of calcium and phosphorus. The food taken in this experiment was very similar to that of the diet of von Wendt in the experiment described above (p. 32), in which he observed a large loss of iron. It differed from von Wendt's diet, however, in that the butter and sugar were omitted and the amounts of bread and egg white were somewhat reduced. The diet furnished, therefore, considerably less fats and carbohydrates and somewhat less protein than that of von Wendt, but the protein and the inorganic nutrients were derived from the same food materials in each case. Hence, if the loss of iron observed by von Wendt was due to the nature of the food taken by him or to its low calcium content, the same effect should be observed here, where the nature of the food was the same and the amount still smaller. Moreover, aside from the special interest attached to the possible confirmation of the views of von Wendt, it was intended that a comparison of the results of the two experiments here described should throw as much light as possible upon the general question of the influence of other inorganic food constituents upon the metabolism of iron. For this reason the second experiment was made to follow the first without intermission and with the smallest practicable alterations in the fuel value of the daily diet and the amounts of nitrogen and iron which it contained.

In order to gain a further insight into the general nutritive condition and food requirement of the subject, and especially to test the question whether the loss of nitrogen, which continued throughout the six days covered by the two experiments, should be attributed primarily to deficiency of protein or of fuel value in the diet, the food was controlled and the urine collected during an "after period" of two days following the second experiment. In this after period the diet furnished approximately the same amount of protein as was taken during the experiment proper, but more fats and carbohydrates. This increase in the fuel value reduced the katabolism of

nitrogen at once and brought about approximate equilibrium of nitrogen upon the first day of the after period, which would appear to justify the statement that the food of the experimental periods contained sufficient protein for the normal needs of the subject, but was deficient in fuel value. The third experiment was carried out five months later than the second, but was preceded by a three-day period during which the diet was the same as in the first experiment.

Each experimental day began at 7 a. m., and the food for the day was taken in three nearly equal meals, at 7.30 a. m. and 12.30 and 6.30 p. m. The urine of each experimental day was mixed, weighed, and sampled for analysis and for the preparation of a composite sample representing the entire experiment.

To facilitate the accurate separation of the feces belonging to each experiment it is customary to take lampblack in gelatin capsules with the first meal of the period. Since the purest available lampblack and capsules both contained iron, the separations were effected in these experiments by mixing pure powdered charcoal with the food material as it was eaten. Charcoal free from iron or other impurity was prepared for the purpose by heating chemically pure sucrose in a covered platinum dish. In order to avoid possibilities of contamination the feces were, as far as practicable, received directly in platinum dishes and burned to ash without previous transfer, drying, or manipulation of any kind. It was therefore necessary to omit the usual proximate analysis and determination of nitrogen. Since, however, the food materials used were all of the most familiar kinds, it is believed that the protein and energy values of the feces can be calculated with only insignificant errors from the results of previous investigations, and that any slight inaccuracy which might be thus introduced into the estimations of fuel value and nitrogen balance are much more than compensated by the increased accuracy and reliability of the figures obtained for iron.

DETAILS OF METABOLISM EXPERIMENT NO. 1.

The experiment was begun at 7 a. m. December 30, 1905, and continued three days.

The weight of the subject (without clothing) was 65 kilograms (143 pounds) at the beginning and 62.5 kilograms (137.5 pounds) at the end of the experiment. It may be noted that the usual weight of this subject (without clothing) is 63 to 66 kilograms in winter and 60 to 63 kilograms in summer.

The daily food consisted of 150 grams of bread (crackers) and 1,500 grams of milk. The crackers furnished 14.6 grams protein, 14.9 grams fat, and 113 grams carbohydrates. The milk furnished 48.4 grams protein, 61.7 grams fat, and 73.2 grams carbohydrates. The total nutritive value of the diet was therefore 63 grams pro-

tein, 76.6 grams fat, and 186.2 grams carbohydrates, the fuel value being 1,690 calories.

The data regarding the income and outgo of mineral constituents are given in the following table:

TABLE 5.—*Income and outgo of mineral constituents in metabolism experiment No. 1 (serial No. 11).*

Kind of material.	Iron.	Calcium oxid.	Magnesium oxid.	Phosphorus.	Nitrogen.
Food per day:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread (crackers)	0.0023	0.042	0.026	0.134	2.34
Milk	.0034	2.609	.260	1.412	7.76
Total daily income	.0057	2.651	.286	1.546	10.10
Feces:					
First day (Dec. 30 to Jan. 1)	.0052				
Second day (Jan. 1–2)	.0040				
Third day (Jan. 2–3)	.0068				
Total for 3 days	.0160	5.630	.510	1.710	(1.38)
Average per day	.0053	1.880	.170	.570	(0.46)
Urine:					
First day (Dec. 30 to Jan. 1)				.850	12.52
Second day (Jan. 1–2)				1.110	13.56
Third day (Jan. 2–3)				1.140	13.19
Total for 3 days	.0006	.630	.570	3.100	39.27
Average per day	.0002	.210	.190	1.030	13.09
Total outgo per day	.0055	2.090	.360	1.600	13.55
Gain (+) or loss (−) per day	+.0002	+.561	−.074	−.054	−3.45

The data given in Table 5 show that on a diet of bread and milk, furnishing 63 grams of protein and 1,690 calories, with only 5.7 milligrams of iron, there was practical equilibrium of iron and phosphorus, a considerable storage of calcium, a slight loss of magnesium, and a considerable loss of nitrogen. These balances are discussed more fully below in connection with those of the other experiments of the series.

DETAILS OF METABOLISM EXPERIMENT NO. 2.

This experiment, which followed the preceding one without intermission, was begun at 7 a. m. January 3, 1906, and continued for three days.

The weight of the subject (without clothing) was approximately 62.5 kilograms (137.5 pounds) both at the beginning and at the end of the experiment.

The daily food consisted of 400 grams of bread (crackers) and 250 grams of coagulated white of egg. This food was taken with about 1,000 grams of distilled water. The crackers furnished 39 grams protein, 39.8 grams fat, and 301.3 grams carbohydrates. The egg white furnished 27.8 grams protein and 0.7 gram fat. The total nutritive value of the diet was therefore 66.8 grams protein, 40.5

grams fat, and 301.3 grams carbohydrates, the total fuel value being 1,833 calories.

The data recording the income and outgo of mineral constituents are given in the following table:

TABLE 6.—*Income and outgo of mineral constituents in metabolism experiment No. 2 (serial No. 12).*

Kind of material.	Iron.	Calcium oxid.	Magnesium oxid.	Phosphorus.	Nitrogen.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Food per day:					
Bread (crackers)	0.0062	0.113	0.070	0.357	6.24
Egg white	.0003	.026	.043	.027	4.45
Total daily income[a]	.0065	.139	.113	.384	10.69
Feces:					
First day (Jan. 3-4)	.0042	.480	.050	.170	....
Second day (Jan. 4-5) } Third day (Jan. 5-6) }	.0212	.960	.190	.500	....
Total for 3 days	.0254	1.440	.240	.670	(2.25)
Average per day	.0085	.480	.080	.220	(0.75)
Urine:					
First day (Jan. 3-4)				.900	13.05
Second day (Jan. 4-5)				.740	13.75
Third day (Jan. 5-6)				.620	12.83
Total for 3 days	.0007	.290	.390	2.260	39.63
Average per day	.0002	.100	.130	.750	13.21
Total outgo per day	.0087	.580	.210	.970	13.96
Gain (+) or loss (−) per day	−.0022	.441	.097	.586	3.27

[a] About 1,000 grams of distilled water was taken daily with this diet.

The results given in Table 6 show that the food was somewhat richer in iron and slightly richer in nitrogen and fuel value, but contained much less lime, magnesia, and phosphorus in the second experiment than in the first. The diet of the second experiment was much less acceptable to the subject than that of the first. While the bread and milk diet was always eaten with excellent appetite, the bread and egg white was always more or less distasteful and appeared to be the cause of a slight tendency toward diarrhea, which developed at the end of the second experiment.

DETAILS OF METABOLISM EXPERIMENT NO. 3.

This experiment was begun at 7 a. m. June 3, 1906, and continued three days. In order that the bodily condition of the subject should be as nearly as possible the same as in the second experiment, the diet of the three days preceding the third experiment was the same as in the first experiment, viz, 150 grams of crackers and 1,500 grams of milk per day.

The weight of the subject (without clothing) was approximately 62.7 kilograms (138 pounds) at the beginning and 61.8 kilograms (136 pounds) at the end of the experiment. The initial weight was

therefore practically the same in this as in the second experiment, and the loss of 0.9 kilogram during the three days was probably due as largely to the hot weather as to the deficient fuel value of the diet.

The daily diet consisted of 450 grams of the same soda crackers as were used in the first and second experiments with on an average 1,200 grams of distilled water per day. The crackers suplied 43.9 grams protein, 44.7 grams fat, and 339 grams carbohydrates, the total fuel value being 1,930 calories.

The average daily income and outgo of mineral constituents is shown in Table 7, which follows:

TABLE 7.—*Income and outgo of mineral constituents in metabolism experiment No. 3 (serial No. 13).*

Kind of material.	Iron.	Calcium oxid.	Magnesium oxid.	Phosphorus.	Nitrogen.
Food per day:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread (crackers)	0.0070	0.126	0.079	0.401	7.02
Distilled water	.0001				
Total daily income	.0071	.130	.080	.400	7.02
Feces:					
Total for three days	.0371	3.690	.380	1.350	(2.10)
Average per day	.0124	1.230	.130	.450	(.70)
Urine:					
First day (June 3–4)		.060	.090	.990	10.64
Second day (June 4–5)		.040	.090	.620	10.46
Third day (June 5–6)		.060	.100	.480	9.77
Total for 3 days		.160	.280	2.090	30.87
Average per day	.0002	.050	.090	.700	10.29
Total outgo per day	.0126	1.280	.220	1.150	10.99
Gain (+) or loss (−) per day	−.0055	−1.150	−.140	−.750	−3.97

While the food did not become positively distasteful during the experiment, there was some lack of appetite and at times a slight feeling of fullness and thirst after meals. The bowels moved less regularly and the feces were not so well formed as in the first experiment.

DISCUSSION OF BALANCES OF INCOME AND OUTGO.

In Table 8 are summarized the average daily balances for each experiment of the five elements studied, viz, iron, calcium, magnesium, phosphorus, and nitrogen.

TABLE 8.—*Summary of results of metabolism experiments—Quantities per day.*

Experiment and ration.	Element.	In food.	In feces.	In urine.	Gain (+) or loss (−).
		Grams.	*Grams.*	*Grams.*	*Grams.*
Experiment No. 1 (serial No. 11).					
Bread (crackers) and milk; fuel value 1,690 calories	Iron	0.0057	0.0053	0.0002	+0.0002
	Calcium oxid	2.65	1.88	.21	+ .56
	Magnesium oxid	.29	.17	.19	− .07
	Phosphorus	1.55	.57	1.03	− .05
	Nitrogen	10.10	[a](.46)	13.09	3.45
Experiment No. 2 (serial No. 12).					
Bread, (crackers) and egg white; fuel value, 1,833 calories	Iron	.0065	.0085	.0002	− .0022
	Calcium oxid	.14	.48	.10	− .44
	Magnesium oxid	.11	.08	.13	− .10
	Phosphorus	.38	.22	.75	.59
	Nitrogen	10.69	[a](.75)	13.21	−3.27
Experiment No. 3 (serial No. 13).					
Bread (crackers) and water; fuel value, 1,930 calories	Iron	.0071	.0124	(.0002)	− .0055
	Calcium oxid	.13	1.23	.05	1.15
	Magnesium oxid	.08	.13	.09	− .14
	Phosphorus	.40	.45	.70	.75
	Nitrogen	7.02	[a](.70)	10.99	3.97

[a] Value estimated from previous experiments.

It will be seen that in each case the fuel value was low and there was a considerable loss of nitrogen. That this loss is attributable to deficiency in fuel value rather than in protein was shown by a short after period following the second experiment. In this after period the fuel value was increased to 2,560 calories per day, with only a slight increase in the protein, and the loss of nitrogen fell at once from about 3 grams to only 0.2 gram per day.

Since the gains and losses of nitrogen and phosphorus can best be discussed in connection with the results of other experiments now in progress, only the balances for iron, lime, and magnesia need be especially considered at this point.

As has been stated in the general description of the experiments, the bread-and-milk diet was intended to give conditions favorable to the maintenance of equilibrium with a small amount of iron, while the second experiment was designed to test von Wendt's view that a deficiency of lime tends to bring about a loss of iron. While no large discrepancy like that observed by von Wendt was found, the iron balances for these two experiments do apparently indicate a more economical metabolism of iron on the bread-and-milk diet than on the bread-and-egg-white diet. With the latter, however, there was, as already noted, some evidence of less perfect digestion, as indicated by diminished appetite and near the end of the experiment a slight tendency toward diarrhea. It was thought possible that these results might perhaps have been due as much to intestinal disturbance resulting from the consumption of the egg white as to the lack of lime in the diet. Unfortunately, the urine from this experiment was lost before there was opportunity to examine it for ethereal sulphates or other evidence of putrefaction. The diet of the third experiment differed from the second in that no egg white was eaten and the amount of

crackers was increased. The nitrogen was lower and the fuel value higher. The loss of nitrogen (indicating metabolism of body tissue) was nearly the same. The diets in the two experiments furnished practically the same amounts of lime, magnesia, and phosphorus, and as a further precaution experiment No. 3 was preceded by a three-day period in which the subject consumed the same kind and amount of food as during the three days preceding experiment No. 2. Moreover, the initial body weight was practically the same for the two experiments. All these facts indicate that the nutritive condition of the subject must have been nearly the same at the beginning of the third as at the beginning of the second experiment. The daily routine and the amount of work performed during the experimental periods was also very similar, so that the substitution of 50 grams of crackers for 250 grams of egg white and the change in season from January to June are the only factors which seem likely to have affected the results.

During experiment No. 3 the amount of water consumed was limited to about the quantity used in experiment No. 2. As the weather was warm, there was sometimes a feeling of thirst and of slight fullness of the stomach after meals. In spite of the drink restriction and the observance of all precautions which suggested themselves, the movements again became somewhat irregular and the stools were found to be unformed. The losses of iron, calcium, and magnesium were greater in this experiment than in the second, and will be seen to be due to increased elimination through the intestine. In this case the urine was examined for simple and ethereal sulphates, and the proportion of the latter was found to be very low (1 : 25), indicating that during this period there was unusually little intestinal putrefaction. Whether the losses which occurred in these experiments were due to the low lime content of the food is not certain. Evidently, however, the metabolism of iron was much more economical in the first experiment, where the food furnished an abundance of calcium. Comparison of the iron and lime balances for the three experiments makes it appear probable that the two are either connected (perhaps in some such way as suggested by von Wendt) or are influenced by a common cause.

The relation of these losses to the looseness of the bowels already noted is made more apparent by the results of analysis of feces passed immediately after the third meal of the after period following the second experiment. These were entirely unformed, and as they came from the food of the same day it is evident that they must have passed through the alimentary canal in an unusually short time. They contained 0.008 gram iron, 0.709 gram calcium oxid, and 0.075 gram magnesium oxid. This material could not have represented more than two-thirds of the food of the day, and while these food

samples were only partially analyzed it is evident that there was on this day an increasing loss of each of the elements accompanying the tendency toward diarrhea. It has already been noted that some tendency in this direction was evident within the experimental periods; not, however, sufficient to prevent the experiment being considered as normal. Even if it be assumed that the irregularity at stool was itself the cause of the increased elimination of iron, the results lose none of their value, for evidently, if a condition so common as slight looseness of the bowels has a decided effect upon the iron elimination, the fact must be taken into account in attempting to estimate the iron requirement of the body.

While the first experiment of this series shows a slight gain of iron with less than 6 milligrams in the food, it is evident that an estimate based upon all of these experiments, together with those of Stockman, must allow at least 10 milligrams per day in order to cover safely such variations as seem to be of frequent occurrence in normal subjects.

GENERAL CONSIDERATIONS REGARDING THE IRON REQUIREMENT.

The experiments described above, which indicate an iron requirement in the neighborhood of 10 milligrams per man per day, were made upon men at occupations involving only light to moderate muscular exercise. Whether active muscular work would increase the demands of the body for iron appears to be a question mainly of theoretical interest in the case of men, since the well-known effect of muscular exercise upon the appetite would ordinarily result in such increase of the general food consumption that the iron requirement would be fully met without any special selection of food materials.

On the other hand, when, as is usually the case with women and children, the food consumption is below that of a man at light exercise the iron content of the food may easily require consideration. Undoubtedly the iron requirement is governed by considerations somewhat different from those which determine the needs of the body for total food, and it may be doubted if the factors which are ordinarily used in computing the results of dietary studies (see p. 59) can be accepted as expressing the relative requirements of men, women, and children with respect to iron. The influence of menstruation, pregnancy, and lactation in women and of growth and development in children may reasonably be supposed to affect the demand for iron to a greater extent than is apparent in the total food requirement.

Early in his investigations Bunge[a] showed that young animals

[a] Ztschr. Physiol. Chem., 13 (1889), p. 399.

of such species as live entirely upon milk for some time after birth are born with a store of iron accumulated during intrauterine life to meet the needs of the suckling period when the growth is rapid and the iron content of the food is small. Bunge regarded it as improbable that the mother can assimilate during the period of pregnancy so much iron as she supplies to the fetus, and therefore advanced the view that even at puberty iron is withdrawn from the general circulation and stored to meet this future need of the female organism, which would explain the frequent occurrence of anemia in girls. A complete experimental demonstration of this hypothesis is obviously impracticable, but it has been confirmed in a measure by the observations of Charrin [a] upon the passage of iron from the spleen to the fetus during pregnancy, while Hugounenq [b] has studied quantitatively the demands of pregnancy upon the mother and considers that the drain upon the inorganic elements is the principal cause of the malnutrition so often observed during this period. According to Hugounenq, the normal child contains at birth about 0.3 gram of iron, of which two-thirds is drawn from the organism of the mother during the last three months, so that it is very important that before and during this period the diet should furnish an abundance of iron, as well as of calcium and phosphorus, since the administration of medicinal compounds of these elements is of little utility. Moreover, the analyses of Camerer and Söldner [c] and of de Lange [d] indicate that the newborn child contains more iron than was found by Hugounenq, in which case the iron requirements of the mother during pregnancy would be correspondingly greater.

In a recent revision of his work on this subject Söldner [e] estimates the iron content of a newborn infant at 0.15 gram per kilogram of body weight. This figure, which although about three times as high as the estimated proportion in the adult body, is considerably lower than most of those previously published, corresponds to 0.50 gram iron (or about a fifth of the entire amount supposed to exist in the body of the mother) in a newborn infant weighing 3.3 kilograms ($7\frac{1}{4}$ pounds).

The manner in which iron passes from mother to fetus has been studied by Hofbauer, whose observations [f] indicate that the mechan-

[a] Compt. Rend. Acad. Sci. [Paris], 128 (1899), p. 1614; abs. in Jour. Chem. Soc. [London], 1899, II, p. 773.

[b] Compt. Rend. Acad. Sci. [Paris], 128 (1899), p. 1054; abs. in Jour. Chem. Soc. [London], 1899, II, p. 503.

[c] Ztschr. Biol., 39 (1900), p. 186; 43 (1902), p. 1; 44 (1903), p. 61; 46 (1905), p. 371.

[d] Ztschr. Biol., 40 (1900), p. 526.

[e] Ztschr. Biol., 44 (1903), p. 61.

[f] Ztschr. Physiol. Chem., 40 (1903), p. 240.

ism of absorption in the placenta is similar to that in the wall of the intestine, and that the iron is obtained, in part at least, by the breaking down of the red corpuscles of the mother's blood. In harmony with this observation, Charrin and Guillemont[a] find during gestation a decrease in the percentage of iron in the blood as well as in the spleen. During normal lactation the daily secretion of milk is about 800 to 1,000 cubic centimeters. The iron content of human milk is, however, uncertain, as recent investigations[b] have given very discordant results, the estimated average of some observers being as low as 0.00012, and of others as high as 0.0005 per cent. From these results the average amount of iron leaving the body daily through the milk might be estimated at any figure from 1 to 5 milligrams. Observations upon nursing infants, however, also give data from which to estimate the amount of iron in the milk. Leichtenstern found[c] that the absolute amount of hemoglobin in the average infant increases slightly during the first six months. It was also found by Abderhalden,[d] in experiments upon young animals, that there was normally a small gain of hemoglobin during the suckling period when no food other than milk was taken. Since most of the iron in the body exists in the form of hemoglobin it would appear that the normal nursing infant must receive in the mother's milk as much iron as it eliminates, a view which is in harmony with Bunge's observation upon rabbits, which also are born with a store of iron, and in which the absolute amount of iron was found to remain nearly constant during the suckling period.[e]

Blanberg[f] has studied the iron contents of infant foces and found in a six-day experiment upon a healthy child 5 months old, living on mother's milk, an average daily elimination of 2.6 milligrams of iron; in a small, sickly child 3 to 4 months old, fed on diluted cow's milk, the average elimination for four days was 2.7 milligrams per day.

These results indicate that the nursing infant normally receives in its mother's milk about 3 milligrams of iron per day, and that the function of lactation must increase the iron requirement of the mother by at least this amount.

---

[a] Compt. Rend. Acad. Sci. [Paris], 133 (1901), p. 182; Jahresber. Tier-Chem., 31 (1901), p. 769.

[b] Camerer and Söldner, loc. cit.; De Lange, loc. cit.; Jolles and Friedjung, Arch. Expt. Path. u. Pharmakol., 46 (1901), p. 247.

[c] Untersuchung ueber den Haemoglobingehalt des Blutes, Leipzig, 1878. Quoted by v. Hösslin, Ztschr. Biol., 18 (1882), p. 612.

[d] Ztschr. Physiol. Chem., 34 (1900–1901), p. 500.

[e] Physiological and Pathological Chemistry. Philadelphia, 1902, 2. Eng. ed., p. 379.

[f] Ztschr. Biol., 41 (1900), pp. 1, 36.

It is to be noted that this is simply an estimate based on what appear to be the best data now available. A similar calculation on the basis of the early analyses of infants' feces by von Hösslin, combined with the most recent and lowest figures for iron in milk published by Camerer and Söldner, would give a much lower result.

The experimental evidence regarding the iron requirement in childhood is mainly indirect. From the data above given it appears that at birth the body contains about three times as much iron per kilogram as is found in the adult. Since Bunge found that rabbits are born with four times the percentage in the full-grown animal, it is not improbable that what Bunge found for the rabbit is also approximately true for the child, i. e., that the absolute iron content remains approximately constant, while the percentage falls as the body weight rises. If this is the case the infant normally nourished on mother's milk will have used up its original store of iron (and reached the same percentage of content of iron as an adult) when the body weight is about three times that at birth—usually in a little over one year. It would appear, therefore, that at about this age in cases of natural feeding, and perhaps somewhat sooner where modified cow's milk has been used (see p. 49), there should begin a selection of food with reference to increasing the iron content of the diet while maintaining its lime and phosphorus content.

Independently of Bunge's work Camerer,[a] as the result of many experiments and observations, had concluded that the full amount of iron (as well as of calcium and phosphorus) received by a naturally nourished child is required for the maintenance of a normal rate of growth and development. It appears, therefore, that if, through disturbance of digestion or through artificial feeding, the assimilation of iron during the first year is less than normal, the amount of iron in the body at the end of the nursing period will be low. Clinical observations show that this is very often the case. It is evident that the food must supply an abundance of iron if it is to replenish the normal store of the body while at the same time providing for the demands of rapid growth.

As compared with men, therefore, the requirements of women and children may be expected to be somewhat higher with respect to iron than with respect to total food, and it would seem desirable that most family dietaries should contain well over 10 milligrams of iron per man per day.

[a] Ztschr. Biol., 43 (1902), p. 1.

IRON IN FOOD MATERIALS.

Little weight can be attached to the statements regarding iron which are to be found in the standard compilations of ash analyses, as these are based largely upon results obtained by methods which greatly overestimated the iron. Generally speaking, it is only since the discussion of iron in food materials was begun by Bunge in 1885 that analyses have been made with special reference to the determination of iron, and the amount of data which appears to be trustworthy is not yet very large. Below are given, for each of the important groups of food materials, the results of previous determinations, which appear to be reliable, and of the determinations made in connection with this investigation.

MEATS, FISH, AND SHELLFISH.

In meat as ordinarily eaten the iron exists largely as hemoglobin, due to the blood contained in the muscular tissue as usually sold and prepared for the table. Muscular tissue washed free from blood contains iron, but the amount is comparatively small. Since fatty tissue is nearly free from iron, the iron content of fat meat is much less than that of lean, and in order to establish any useful estimate of the amount of iron in meat it is practically necessary to consider the lean tissue alone or to refer the iron to the protein content rather than to the gross weight of the meat, and even when expressed on the former basis the results will be influenced by the extent to which the blood has been either accidentally or intentionally removed from the muscle. Most of the determinations of iron in meat have been made upon lean muscular tissue containing its normal proportion of blood.

Bunge[a] found 0.0035 per cent of iron in fat-free beef, and estimates the average iron content of the water-free, fat-free substance to be 0.0169 per cent.

Kunkel[b] found 0.0048 per cent in (fresh) dog's muscle, both in an animal which had been fed much, and in one which had received little iron in the food.

Stockman[c] reported 0.0039 per cent of iron in lean beefsteak.

Katz[d] determined the inorganic constituents, including iron, in the flesh of many animals, but his work affords no evidence that special attention was paid to the iron determinations and in most

[a] Ztschr. Physiol. Chem., 9 (1885): Physiological and Pathological Chemistry. Philadelphia. 1902. 2. Eng. ed., p. 376.

[b] Arch. Physiol. [Pflüger], 50 (1891), p. 1.

[c] Jour. Physiol., 18 (1895), p. 484.

[d] Arch. Physiol. [Pflüger], 63 (1896), p. 1.

cases there is strong probability that the results are somewhat too high. Another extended series of determinations of iron in the flesh of different animals has been published by Schmey,[a] who found no constant difference in iron content between the light and dark meats of the same animal and only a small increase as the result of feeding large amounts of iron. Schmey's results indicate large differences in the amounts of iron in the flesh of different animals, but it appears altogether probable that most of these differences are either accidental or due to analytical errors. The method used by Schmey was very similar to one of those employed by Bunge, and involved the precipitation and weighing of iron as phosphate. Since the precipitates obtained varied greatly in amount there is a probability that the high results are too high through contamination of the precipitate, and the low results too low through incomplete formation of these precipitates in the extremely dilute solutions from which they were obtained. This would account for the extreme variations reported by Schmey while the mean result of all his determinations might still be approximately correct. The results of Katz are more uniform than those of Schmey, but as already indicated are probably quite generally too high. Thus while we can not accept the results of either of these investigations in detail, we can use the results of each in the verification and interpretation of others. The view that the differences attributed to species by Schmey are more probably due to other causes is confirmed by comparing the results found by Schmey and Katz, who found in the dry substance of dog muscle 0.0205 and 0.0193 per cent iron, respectively; in pig muscle, 0.0156 and 0.0218 per cent; in chicken muscle, 0.0106 and 0.0295 per cent, and in rabbit muscle, 0.0055 and 0.0233 per cent.

It may therefore be concluded that in spite of the great number of results given by Schmey and Katz no certain difference in iron content can be stated to exist either between the light and dark muscles of the same animal or between the muscles of different animals. The general average of Schmey's results for 16 samples, representing 10 kinds of edible flesh, was approximately 0.004 per cent.

In connection with the present investigation iron has been determined in two samples of fresh beef free from visible fat, and two dried samples of beef which had been nearly freed from fat, ground, and pressed sufficiently to prevent any further separation of fluid from the ground samples on standing.[b]

The fresh beef free from visible fat contained the following percentages of iron: First sample, 0.00372 per cent; second sample, 0.00397 per cent; average, 0.00385 per cent.

---

[a] Ztschr. Physiol. Chem., 39 (1903), p. 215.

[b] These samples were from the same lot as the beef ordinarily used in the experiments with men in the respiration calorimeter at Middletown, Conn.

The estimated amount of dry matter in such fresh beef is about 26 per cent, so that these figures correspond to an average of 0.0148 per cent of iron in the dry substance.

The lean beef which had been ground and pressed contained percentages of iron in the dry substance as follows: First sample, 0.0101 per cent; second sample, 0.0105 per cent; average, 0.0103 per cent.

It is evident, therefore, that the pressure to which this meat had been subjected in order to prevent subsequent separation of fluid resulted in the removal of nearly one-third of the iron.

For fresh lean meat containing the full proportion of blood, the results obtained by Bunge, by Stockman, and by ourselves are in satisfactory agreement, and afford an average figure which can be accepted with little danger of serious error. This average figure for the results of the three independent investigations is 0.00375 per cent iron in the fresh meat free from visible fat. The mean result obtained by Schmey is only slightly higher, and therefore tends to confirm this average.

In order to make this result available for the estimation of the iron contents of samples containing different proportions of fat, it is convenient to state it in the form of a ratio of iron to protein. Fresh meat, free from visible fat, such as these samples, which contained 0.00375 per cent of iron, has been found by many previous analyses to contain about 23 per cent of protein. The ratio is therefore 16.3 milligrams of iron to 100 grams of protein, but since there is likely to be some reduction of the iron content through loss of blood in preparing the meat for food, it is estimated that in round numbers meat contains 15 milligrams of iron to 100 grams of protein.

In the absence of satisfactory evidence of differences in the flesh of different animals, or of animals fed in different ways, this ratio has been applied to the meats in general in estimating the amounts of iron in typical dietaries as described further on.

In the flesh of the river crab (crayfish?) Baldoni [a] found 0.002 to 0.003 per cent of iron, indicating a ratio of iron to protein nearly as high as that here adopted for meats. In connection with an extended study of the physiology of the salmon, Grieg [b] determined the amount of iron in the principal organs and tissues of the salmon before and after the long sojourn in fresh water. Reducing the results as given by Grieg to the basis of percentage of iron in the muscles we obtain: For the flesh of the salmon taken in the estuary in May, 0.0017 per cent iron; for that from the upper reaches of the river in autumn, 0.0012 per cent of iron. A single sample of codfish flesh analyzed in connection with this investigation showed a much lower figure, 0.0004 per cent of iron in the fresh substance. On the

[a] Arch. Expt. Path. u. Pharmakol., 52 (1904), p. 61.

[b] Jour. Physiol., 22 (1898), p. 355.

other hand, in shellfish which are eaten without removal of the livers the ratio of iron to protein is perhaps as high as in meat, since Baldoni [a] and Zeleski [b] found from 0.0074 to 0.0082 per cent in the livers of crabs.

The iron of meat, as already mentioned, is largely due to the blood retained in the muscular tissue. The nutritive value of this blood is often questioned. So far as the iron compounds of the blood are concerned it seems to be established by many investigations, of which those of Häusermann and Aberhalden (see p. 19) are perhaps the most important, that hemoglobin and hematin are absorbed and assimilated, though probably not to such good advantage as the iron-proteid compounds of eggs, milk, and vegetable foods.

EGGS.

Socin in 1891 [c] published the results of iron determinations in eight samples of egg yolk, which averaged 0.00754 per cent. Assuming that the edible portion of egg consists approximately of two-thirds white and one-third yolk, and assuming for the white the iron content (0.00014 per cent) found in our own experiment (p. 31), the average amount of iron in the entire edible portion of the eggs examined by Socin may be estimated at approximately 0.0026 per cent.

Lages and Pingel [d] found an average of 0.00329 per cent of iron in the entire edible portion. Hoffmann [e] obtained as the mean of ten determinations, 0.00845 per cent of iron in the yolk, which calculated as in the case of Socin's result, indicates 0.00291 per cent in the combined yolk and white. Hartung [f] found as the average of two samples representing ten eggs, 0.00307 per cent of iron in the edible portion.

Three eggs were analyzed in connection with this investigation. The first, an egg with a dark shell, contained 0.00317 per cent iron in the edible portion; the second, an egg with a lighter colored shell, 0.00309 per cent; and the third, a very light-colored egg, 0.00277 per cent. The average for the three would be 0.00301 per cent.

The mean of the averages estimated from the investigations just cited is 0.00297 per cent iron in the edible portion. On the basis of available data we may therefore accept the estimate that the edible portion of hens' eggs contains 0.003 per cent of iron.

It is sometimes stated that eggs with dark-colored shells are richer in iron than eggs whose shells contain less pigment. The three eggs

---

[a] Loc. cit.

[b] Ztschr. Physiol. Chem., 10 (1886), p. 453.

[c] Ztschr. Physiol. Chem., 15 (1890–91), p. 93.

[d] Nutzgeflugelzucht (1900), p. 372, quoted by Hartung.

[e] Ztschr. Analyt. Chem., 40 (1901), p. 450.

[f] Ztschr. Biol., 43 (1902), p. 195.

analyzed in this investigation showed differences in iron content which appear to support this view, but the variation is not great and the results do not establish any necessary or striking connection between color of shell and iron content of the egg.

Whether the iron content of eggs can be increased by giving to poultry food rich in iron is a disputed question. Hoffmann found an increased percentage of iron in the eggs of hens which had been given hemogallol in addition to ordinary food, and Hartung obtained a similar result in two of three experiments. The increase becomes apparent only after the feeding has been continued for some time and is not very striking in most cases. Kreis[a] failed to obtain any such increase.

There can be no doubt regarding the assimilation and utilization of the iron compounds of eggs, since they serve for the production of all the iron-holding substances of the blood and tissues of the chick, there being no possibility of the introduction of iron from without during incubation.

MILK.

Bunge,[b] in 1875, gave the iron content of cow's milk as equivalent to 0.00024 per cent. In a recent summary[c] he gives the iron content as 2.3 milligrams per 100 grams of dry solids, equivalent to 0.0003 per cent in the fresh milk.

Mendes de Leon[d] gave higher figures, averaging 0.0004 per cent, but admitted that his samples may have been contaminated with iron during handling.

Stockman[e] found in three samples 0.0002, 0.00037, and 0.00042 per cent of iron, respectively.

Abderhalden,[f] believing that part of the iron found in commercial milk may come from the utensils or other foreign sources, made a careful examination of milk direct from the udder. This showed 1.8 milligrams of iron per 100 grams of dry solids, equivalent to 0.00023 per cent of iron in the fresh milk.

In the course of the present investigation iron was determined in five samples of cow's milk, four of which were of accurately known origin and represented the mixed product of about 500 cows, while the fifth was a composite commercial sample prepared by mixing equal portions from nine bottles of "selected" milk furnished by one

[a] Jahresber. Chem. Lab. Basel, 1900, p. 15; abs. in Jahresber. Tier-Chem., 1902, p. 563.

[b] Ztschr. Biol., 10 (1875), p. 295.

[c] Ibid., 45 (1904), p. 532.

[d] Arch. Hyg., 7 (1887), p. 286.

[e] Jour. Physiol., 18 (1895), p. 484.

[f] Ztschr. Biol., 39 (1898), p. 218.

of the largest dealers in New York City. All of the samples had been produced and handled under good sanitary conditions and bottled while still fresh, so that the danger of contamination with iron from utensils or otherwise was reduced to a minimum, and at the same time each sample represented the mixed milk of a large number of cows, as is now commonly the case with the milk sold in large cities. The five samples yielded the following percentages of iron: No. 1, 0.000285 per cent; No. 2, 0.000214; No. 3, 0.000243; No. 4, 0.000232; No. 5, 0.000228; average, 0.00024 per cent.

The average of these five analyses is in almost exact accord with the recent work of Abderhalden, and is further confirmed by Bunge and in the main also by Stockman. This average has therefore been adopted in the estimation of the iron supplied by milk and its products in the dietary studies discussed further on.

In order to ascertain whether the iron compounds in milk tend to condense upon the fat globules or for any other reason are altered in their distribution by the rising of the cream the first sample was preserved by means of formaldehyde, and after the cream had risen the iron and nitrogen contents were determined separately in the upper half containing all of the cream and in the lower half which consisted entirely of skimmed milk. These analyses showed in the upper half 0.000277 per cent of iron and 0.54 per cent of nitrogen; in the lower half 0.000293 per cent of iron and 0.59 per cent of nitrogen.

It is evident, therefore, that the ratio of iron to nitrogen is practically the same in the cream as in the skimmed milk, and that both are lower in the former than in the latter in proportion as the fat globules have displaced the milk serum in which the proteids and the iron compounds are contained.

It can not be doubted that the iron of milk is readily absorbed and assimilated, since this constitutes the sole natural source of iron for all young mammals during a period of rapid growth. Moreover the metabolism of the experiments of von Wendt and those described in this bulletin would indicate that iron of milk is likely to be utilized to especially good advantage on account of its association with a high proportion of calcium.

The question of the iron supply of infants fed upon diluted or modified cow's milk should, however, be considered at this point. It is now generally recognized that the best substitute for mother's milk is obtained by diluting cream with a solution of milk sugar, the product being usually known as modified milk. By varying the richness of the cream and the amounts of water and milk sugar added the composition of the modified milk can be controlled at will. Since the proteids of cow's milk are often not easily digested by infants it is customary to feed mixtures containing only a small

percentage of protein at first and to increase the protein only very gradually. It is therefore important to recognize that the iron content of cow's milk is little if any higher than that of human milk, while the protein content is at least twice as high; and further, that any modification of cow's milk which reduces its protein content must reduce the iron content in practically the same proportion, so that an infant fed upon cow's milk modified or diluted to contain less than 3 per cent of proteids is receiving food poorer in iron than human milk. According to present estimates an infant fed on any modification of cow's milk must consume the equivalent of a quart of undiluted milk or cream in order to obtain as much iron as is supplied daily in the milk of the average healthy nursing mother.

It has long been recognized that the iron content of the milk can be increased somewhat by the administration of iron in forms other than those occurring in ordinary foods. Whether the extra iron thus brought into the milk is of similar nutritive value to that which it normally contains has not been established. Only a few typical investigations of the effect of administered iron compounds upon the milk need be mentioned.

Rombeau and Rosaleur,[a] in 1856, found the iron content of the milk increased after feeding finely divided metallic iron or iron citrate.

Lewald[b] found that the serum of the milk of a goat fed on hay and meal contained only a trace of iron. The goat was then given 20 drops of tincture of iron chlorid diluted with water and the milk serum was tested at each milking. He found that for about forty-eight hours the iron in the milk serum was markedly increased.

On giving 0.732 gram of black oxid of iron suspended in water no effect could be seen in the milk drawn twelve hours later, but that drawn twenty-four hours after giving the oxid showed a strong iron reaction. The same result was obtained on repeating the experiment. Milk drawn thirty-six to sixty hours after the administration of the oxid showed only the normal amount of iron. The fact that so much time is required for appearance of iron in these cases was explained by the assumption that the oxid is dissolved and an albuminate formed in the stomach. The albuminate is later absorbed and metabolized.

Bristow[c] fed lactate of iron to a goat, gradually increasing the amount until 3 grams per day were ingested. The iron content of the milk rose to a maximum of 10 milligrams per day in excess of that found before the beginning of the experiment.

---

[a] Bul. Gén. Thér. Méd. et Chirurg., 50 (1856), p. 355.

[b] Untersuchungen ueber den Uebergang von Arzneimitteln in die Milch. Breslau, 1857.

[c] Arch. Path. Anat. u. Physiol. [Virchow], 45 (1869), p. 98.

Mendes de Leon [a] found no increase in the iron content of the milk after feeding 1 gram lactas ferrosus per day for fourteen days.

Stohmann, in a work published in 1898,[b] states that as the result of giving acid food which has been allowed to stand over night in iron vessels, cow's milk may contain so much iron as to be unfit for cheese making, since the curd obtained from such milk is subject to a bluish discoloration. This, together with the further statement that the iron in the milk can be shown in these cases by the coloration obtained on adding tannin, indicates that the extra iron existed either as a salt or in some very loose form of organic combination.

Giordani [c] has recently published the results of experiments in which iron was given to goats by intramuscular injection of a 10 per cent solution of the citrate. The injections were given repeatedly in increasing amounts and resulted in a marked increase of the iron content of the milk. The extra iron thus introduced into the milk was stated to be in organic combination, probably with the proteids.

CEREAL PRODUCTS.

Although analyses of the ashes of cereal grains and their milling products have been quite numerous most of them have not included accurate determinations of iron, and it is only from those investigations which deal directly with iron problems that data sufficiently accurate for the purposes of this compilation are to be expected.

The results of such determinations as appear to be reasonably reliable are given, together with those made in the course of the present investigations, in Table 9. In much of the work of Bunge and of Häusermann, iron was determined both gravimetrically and volumetrically, the average of the results thus obtained being generally used in the original papers. As subsequent experience has shown that the results by their gravimetric method are quite likely to be too high and those by titration are much more reliable, the latter have been taken instead of the average in those cases in which the full analytical data of these investigators were available. Data given by Bunge on the basis of water-free substance have been reduced to the basis of average water content of commercial substance, using the average figures for moisture given in the compilation of analyses of American food materials published by this Office.[d] A description of the samples analyzed in connection with the present investigation follows:

Sample No. 1. Patent barley flour, sold in tin boxes under the name of the maker and especially recommended for infant feeding. The sample contained 10.27 per cent moisture, 7.90 per cent protein, and 0.64 per cent ash.

---

[a] Arch. Hyg., 7 (1887), p. 306.

[b] Milch und Molkereiproducte. Braunschweig, 1898, p. 785.

[c] Rev. Mens. Mal. Enfance, 20 (1902), p. 385; in Jahresber. Tier.-Chem., 32 (1902), p. 999.

[d] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, rev.

Sample No. 2. Ordinary yellow corn meal, from retail grocery, New York City.

Sample No. 3. A medium-early variety of sweet corn grown to maturity on a clay-loam soil in central Ohio. The sample as analyzed contained 11.15 per cent of moisture.

Sample No. 4. One of the well-known brands of oatmeal sold in two-pound packages. The sample as analyzed contained 11.15 per cent of moisture.

Sample No. 5. First quality rice, from retail grocery, New York City.

Sample No. 6. One of the standard brands of fine white flour. The sample contained 9.48 per cent moisture, 10.81 per cent protein, and 0.43 per cent ash.

Sample No. 7. Another well-known brand of fine flour.

Sample No. 8. White bread fresh from bakery, New York City.

Sample No. 9. Sample sold as "whole-wheat" or "entire-wheat" bread; was quite brown in color, but showed no visible fiber and evidently did not contain the outermost layers of the grain.

Sample No. 10. One of the widely advertised brands of prepared "whole-wheat" breakfast food.

Sample No. 11. Entire grains of wheat grown on experimental farm in Kansas, selected as pure and typical by Mr. M. A. Carleton, cerealist, U. S. Department of Agriculture.

The analytical data referred to follow:

TABLE 9.—*Percentages of iron found in cereal grains and their products.*

Kind of material.	Observer.	Iron.
		Per cent.
Barley, flour, patent (sample No. 1)	Sherman	0.0010
Barley, pearled	Häusermann	.00125
Barley, entire grain	do	.0040
Corn meal, yellow (sample No. 2)	Sherman	.00115
Corn, mature sweet corn, entire grain (sample No. 3)	do	.0029
Oatmeal, Scotch	Stockman	.0035
Oatmeal, American (sample No. 4)	Sherman	.0037
Rice, polished (sample No. 5)	do	.0006
Rice (from Japan)	Häusermann	.0009
Rice, used for feeding animals	Bunge	.0019
Rye, entire grain (minimum)	do	.0033
Rye, entire grain (maximum)	do	.0041
Wheat flour (sample No. 6)	Sherman	.0013
Wheat flour (sample No. 7)	do	.0017
Wheat flour	Häusermann	.0014
Wheat bread, white, fresh (sample No. 8)	Sherman	.0007
Wheat bread, white, fresh (minimum)	Bunge	.0007
Wheat bread, white, fresh (maximum)	do	.0010
So-called "entire wheat" bread, fresh (sample No. 9)	Sherman	.0013
Wheat, breakfast food (sample No. 10)	do	.0057
Wheat, entire grain (sample No. 11)	do	.0052
Wheat, entire grain (minimum)	Bunge	.0045
Wheat, entire grain (maximum)	do	.0050

It is apparent that all the grains contain considerable iron, the greater part of which is lost in the ordinary milling processes. The iron thus lost is contained both in the germ and in the integument of the grain. The iron of the germ appears to play an important part in the sprouting of the seed and the nutrition of the young plant. It is thus readily available to the vegetable metabolism, and there is no reason to doubt that it is also readily digested and assimilated as food. The germ is rejected in the preparation of patent grades of flour for bread making, but is often utilized in the form of breakfast food.

The digestibility and nutritive value of the iron compounds in the outer layers of the grains probably depends to a large extent upon the fineness of grinding of this material. Feeding experiments made upon rats by Bunge [a] for the express purpose of testing the point indicate that the iron of the bran is assimilated by the animal body and promotes the formation of hemoglobin. A litter of eight rats was divided into two groups of four each, one group fed upon bread from fine flour, the other upon bread made from flour including the bran. At the end of the fifth, sixth, eighth, and ninth weeks, respectively, one rat of each group was killed, and the gain in weight, the total amount of hemoglobin, and the percentage of hemoglobin in the entire body were determined. The average results were as follows:

TABLE 10.—*Effect of kind of bread on iron content of body in experiments with rats.*

Kind of ration.	Gain in weight of body.	Total hemoglobin in body.	Proportion of hemoglobin in body.
	Grams.	*Gram.*	*Per cent.*
White bread	4.81	0.2395	0.613
Coarse bread	20.76	.3492	.714

The greater growth of the bran-fed rats may have been due to abundance of other elements, as phosphorus, calcium, and magnesium, as well as of iron; but since the percentage as well as the absolute amount of hemoglobin was increased, it seems altogether probable that the iron of the bran was absorbed and utilized for blood formation. In his treaties on bread Goodfellow [b] states that "whole-meal bread contains much more iron than white bread, and yields a greater proportion to the body."

Petit [c] studied the iron compounds of the barley grain, separating the inorganic from the organic forms by extraction with a 1 per cent solution of hydrochloric acid in absolute alcohol (Bunge's reagent). Nearly all of the iron in the barley was found to exist in organic combination and the greater part apparently as nucleoproteid in the germ and outer layers of the grain. A preparation of such nucleoproteid was analyzed, with the following results: Carbon, 43.18 per cent; hydrogen, 6.64 per cent; nitrogen, 12.86 per cent; phosphorus, 1.11 per cent; iron, 0.195 per cent; silica, 3.2 per cent; "ash," 6.2 per cent, and oxygen (by difference), 31.1 per cent. While the high figures for silica and ash indicate that the preparation may not have been entirely pure, the analytical data support the view that the sub-

[a] Ztschr. Physiol. Chem., 25 (1898), p. 36.

[b] The Dietetic Value of Bread. New York, 1892. p. 178.

[c] Compt. Rend. Acad. Sci. [Paris], 115 (1892), p. 246; 116 (1893), p. 995.

stance is a typical iron-holding nucleoproteid, such as were separated by Spitzer from various animal organs.

VEGETABLES.

In view of the fact that iron is an essential constituent of the chromatin of vegetable as well as animal cells, it is to be expected that relatively large amounts will be found in the most active cells, including the chlorophyll cells in which assimilation takes place. While Molisch's conclusion that iron is not an essential element of the chlorophyll molecule is now generally accepted, there is no doubt that iron in organic combination is essential to the activities of the chlorophyll apparatus in the assimilating cells. Undoubtedly, however, many of the ash analyses included in such compilations as those of Wolff and König greatly overestimate the iron content of green vegetables, as was pointed out by Bunge[a] in 1892.

Stoklasa[b] has separated from onions (*Allium cepa*) a substance very similar to the hematogen obtained by Bunge from egg yolk, but containing a much higher proportion of iron, as indicated by the analysis: Carbon, 43.05 per cent; hydrogen, 5.56 per cent; nitrogen, 15.13 per cent; phosphorus, 6.21 per cent; iron, 1.68 per cent; sulphur, 0.28 per cent; oxygen, 28.09 per cent. Preparations showing similar properties (but for which no analyses are reported) were obtained by Stoklasa from peas and from mushrooms.

These results, together with those obtained by Petit in the examination of barley (see above), confirm Bunge's view that the iron of vegetable foods exists in forms similar to the hematogen obtained by him from egg yolk.

In Table 11 are given the percentages of iron found in several typical vegetables, only such data being included as have been reported in connection with investigations in which attention was devoted especially to iron. A description of such samples as were analyzed by the author follows:

Sample No. 1. "Snowflake" navy beans, said to have been grown upon a dark, heavy soil in Washington County, N. Y. The sample contained 11.60 per cent moisture, and 0.44 per cent phosphorus.

Sample No. 2. An early variety of bush Lima beans grown, according to information obtained from the dealer, upon a clay soil in New Jersey. The sample contained 7.85 per cent moisture.

Sample No. 3. String beans obtained from local market (New York City). Before analysis the pods were thoroughly cleaned and the tips and strings removed as in preparation for cooking.

Sample No. 4. Cabbage obtained in city market in March. The portion taken for analysis represented the entire edible portion and contained 91.9 per cent water.

---

[a] Ztschr. Physiol. Chem., 16 (1892), pp. 180, 181.

[b] Compt. Rend., Acad. Sci. [Paris], 127 (1898), p. 282.

Sample No. 5. "Shaker's Early" sweet corn grown to maturity on clay-loam soil in Ohio. Sample contained 10 per cent moisture.

Sample No. 6. Lettuce obtained in New York market in winter. Contained 95.2 per cent moisture after thorough washing and draining. The color of the ash indicated notable amounts of manganese.

Sample No. 7. An extra early market pea obtained in mature state from seedsman in New York City, and said to have been grown in Washington County, N. Y. The sample contained 10.9 per cent moisture and 0.37 per cent phosphorus.

Sample No. 8. A "second early" pea obtained from seedsman as in the preceding case, and said to have been grown on an alluvial soil in central Michigan. The sample as analyzed contained 9.3 per cent moisture.

Sample No. 9. The result given is the average of two analyses of different samples from the same lot of typical medium-sized potatoes—variety not ascertained. The individual results were 0.00127 and 0.00118 per cent iron. The same samples examined by the thiocyanate calorimetric method gave 0.00137 per cent and 0.00114 per cent, respectively.

Sample No. 10. Two determinations were made upon different specimens from the same lot. Neither the origin nor the variety of these sweet potatoes is known. The specimens analyzed were of average size and normal appearance.

Sample No. 11. A sample of spinach obtained from retail grocery. It evidently contained less moisture than when perfectly fresh. Moisture determination yielded 89.9 per cent, showing 10.1 per cent solids, whereas the average given in the standard tables is only 7.7 per cent solids. The percentage of iron shown in the table is therefore about one-third higher than the sample would have contained if the average amount of water had been present.

Sample No. 12. The sample of tomato represented a single fruit obtained from a retail grocery in March. The origin and manner of growth were not known. The tomato contained 95 per cent water.

Sample No. 13. The turnips analyzed were of a small round white variety, and were obtained from a city grocery in winter. The sample contained 92 per cent moisture and 0.6 per cent ash.

The analytical data follow:

TABLE 11.—*Percentages of iron in the edible portion of vegetables.*

Kind of material.	Observer.	Iron.
		Per cent.
Asparagus	Häusermann	0.0012
Beans, dried, as purchased (sample No. 1)	Sherman	.0067
Beans, dried, Lima, as purchased (sample No. 2)	do	.0072
Beans, dried, white	Bunge	.0073
Beans, string, fresh (sample No. 3)	Sherman	.0016
Cabbage, edible portion (sample No. 4)	do	.0009
Cabbage, inner yellow leaves	Häusermann	.0004
Cabbage, outer green leaves	do	.0014
Carrots	do	.0010
Corn, sweet, dried (sample No. 5)	Sherman	.0029
Lettuce (sample No. 6)	do	.0003
Peas, dried, smooth variety (sample No. 7)	do	.0048
Peas, dried, wrinkled variety (sample No. 8)	do	.0064
Peas, dried (minimum)	Bunge	.0056
Peas, dried (maximum)	do	.0060
Potatoes, peeled (sample No. 9)	Sherman	.0012
Potatoes	Bunge	.0014
Sweet potatoes, peeled (sample No. 10)	Sherman	.0005
Spinach (sample No. 11)	do	[a].0038
Spinach	Bunge	[a].0043
Do	Badoni	.0020
Tomato, peeled (sample No. 12)	Sherman	.0004
Turnip, peeled (sample No. 13)	do	.0006

[a] These samples contained less than the average amounts of water; the corresponding figures with average moisture content would be about three-fourths of those here given.

Since the amount of analytical data now available is not sufficient to justify separate estimates of the iron content of each of the common vegetables, a number of them have been divided into two groups, and a single figure has been adopted as a tentative estimate of the average percentage of iron for the materials contained in the group. The estimates used in computing the results of dietary studies (pp. 59–75) are as follows: Asparagus, cabbage, celery, collards, greens, lettuce, onions, and rhubarb, 0.0008 per cent of iron; beets, carrots, parsnips, radishes, sweet potatoes, and turnips, 0.0006 per cent of iron.

FRUITS AND NUTS.

The importance of fruits and nuts as food being now quite generally recognized and advocated, it is probable that their use will steadily increase and that in many dietaries they will be found to furnish an important proportion of both the organic and inorganic nutrients. An especial interest attaches to the iron contents of such fruits as can be used in the dietaries of young children, since the practical value of fruit in such cases is undoubted, and it is also highly desirable that the foods used at this age shall furnish an abundance of iron to meet the demands of blood and tissue formation in the body.

In Table 12 are given the data which have been found on record which appear to be sufficiently accurate to warrant acceptance, as well as the results of analyses made by the author. No descriptions of individual samples are given in connection with this table, since all of the fruits and nuts analyzed were obtained in retail city markets and none is of accurately known origin.

Considering the water content of the fruits as purchased and analyzed, the proportion of iron is, in most cases, quite high. The analyses show, of course, the total percentage of iron found in those portions which are ordinarily eaten. When, as in the case of bananas, figs, and strawberries, the "edible portion" includes the seeds, it is probable that the percentage of iron found by analysis and shown in the table is appreciably higher than that actually available for absorption and assimilation.

TABLE 12.—*Iron in the edible portion of fruits and nuts.*

Kind of material.	Observer.	Iron.
		Per cent.
Apples	Sherman	0.0003
Do	Bunge	.0003
Bananas	Sherman	.0008
Cherries, red	Bunge	.0003
Cherries, black	do	.0004
Do	Häusermann	.0014
Dates	Bunge	.0018
Figs	Häusermann	.0030
Grapes	Bunge	.0013
Huckleberries	Häusermann	.0010
Oranges	Bunge	.0002
Pears	do	.0003
Plums	do	.0006
Prunes, dried	Sherman	.0029
Raisins, seeded	do	.0036
Raspberries	Häusermann	.0006
Strawberries	Bunge	.0009
Almonds, peeled	Häusermann	.0047
Hazlenuts, peeled	do	.0041
Peanuts, peeled	Sherman	.0020
Cocoa beans	Bunge	.0024

In the computation of iron in dietary studies (pp. 59–75) it has been necessary to assume the composition of a number of fruit preparations. For this purpose it is assumed that the average iron content of canned fruits, fruit butters, jams, jellies, etc., is approximately 0.0003 per cent.

THE IRON CONTENT OF TYPICAL FOODS IN RELATION TO TOTAL SOLIDS, PROTEIN, AND FUEL VALUE.

In the preceding pages the percentages of iron are given on the basis of edible material as ordinarily purchased. This is in accordance with the custom followed in the series of nutrition investigations to which this study belongs, and has the advantage of presenting the analytical results in form convenient for use in computing dietaries from the data of food purchased or prepared for cooking. From other points of view, however, it is likely to lead to confusion, especially in cases where the water content varies greatly. Thus the percentages of iron in some of the fresh fruits and vegetables appear from the foregoing tables to be very low, while the same results reduced to the basis of dry solids would show that the proportion of iron in the actual nutritive matter is quite high. It is also important to consider the relative amounts of iron contained in such quantities of different foods as will furnish the same number of grams of protein or the same potential energy expressed as calories.

The iron contents of typical foods have therefore been calculated so as to show their relations to the total solids of the foods and to the protein and fuel value which they furnish. The results thus calculated, from the data for iron obtained in this investigation, and from the average proximate composition as given in a compilation of American analyses,[a] are shown in Table 13.

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, rev.

TABLE 13.—*Iron of typical foods in relation to solids, protein, and fuel value.*

Food material.	Iron per 100 grams of solids.	Iron per 100 grams of protein.	Iron per 3,000 calories.
	Milligrams.	*Milligrams.*	*Milligrams.*
Beef, free from visible fat	14	16	97
Beef, round steak, medium fat	8	16	47
Eggs, entire edible portion	11.4	21.5	57
Milk, whole	1.7	7.3	10
Milk, skimmed	2.5	7.3	20
Cream (18.5 per cent fat)	.8	7.3	3.6
Barley flour, patent	1.1	12.8	8.3
Corn meal	1.3	12.5	9.5
Oatmeal	4.1	22.4	26.4
Rice	.8	10	5.8
Wheat flour (fine), white bread or crackers	1.6	14	12.8
Wheat, entire grain	5.7	37	42
Beans, Lima, dried	8.0	40	60
Beans, pea or "navy," dried	7.5	30	55
String beans, fresh, with pods	14.8	70	112
Cabbage	11	56	84
Corn, sweet	3.2	26	23
Peas, dried	6.2	23	46
Potatoes	5.7	55	42
Spinach	37	135	350
Turnips	7.5	49	47
Apples	2.0	78	15
Grapes, raisins	1.2	137	30
Prunes, dried	3.3	136	28
Peanuts	2.2	7.9	10.8

Among typical food materials omitted from the above table because of containing little, if any, iron may be mentioned fat pork, bacon, lard and suet, butter, salad oil, sugars, starches, and confectionery. All of these foods have high fuel value, and many are very economical and highly important elements in a normal dietary. Excessive use of these foods, however, would tend to satisfy the appetite and supply the body with the needed fuel without furnishing the desirable amount of iron. On the other hand, the fruits and fresh vegetables are often regarded as of low nutritive value because of their high water content and low proportions of protein and fat, but it is largely this property which makes them especially important as sources of food-iron, because they can be added to the diet without replacing the staple foods of high calorific and protein value and without making the total food consumption excessive. Thus the above table shows plainly that the ratio of iron both to protein and to fuel value is high in nearly all of the typical fruits and vegetables, so that in most cases it would be necessary to increase only slightly the proportion of protein and fuel value derived from these sources in order to effect a material increase in the iron content of the dietary. The iron content of eggs is also high, but the cost of these is sometimes almost prohibitive for families of limited means, while present methods of drying and preserving tend to equalize the cost and increase the available variety of fruits and vegetables throughout the year. The ratio of iron to fuel value is also high in lean meat, but here, as has already been pointed out, the iron exists largely in the form of hemoglobin, which appears to be of distinctly lower nutritive value than the iron compounds of milk, eggs, and

foods of vegetable origin. Moreover, there is now a general agreement among medical authorities that little meat should be used in the dietaries of young children, where, as already explained, the supply of food-iron is of the greatest importance. Hence it appears that at least in families where there are young children it would be a mistake to rely largely upon the iron compounds of meat. As is well known, von Noorden is one of the most prominent and consistent advocates of a diet rich in protein and of the liberal use of lean meat in the adult dietary. The following statements from one of his most recent publications [a] are therefore of especial interest:

> The necessity of a generous supply of vegetables and fruits must be particularly emphasized. They are of the greatest importance for the normal development of the body and of all its functions. As far as children are concerned, we believe we could do better by following the dietary of the most rigid vegetarians than by feeding the children as though they were carnivora, according to the bad custom which is still quite prevalent. At this place it is particularly appropriate to emphasize sharply the importance of green vegetables, since we are practically dependent upon the vegetable kingdom for the greater part of the iron—which occurs in vegetables in the form of highly constituted ferruginous nucleo-albumins (Bunge). Although other combinations of iron (iron salts, organic preparations of iron of simple molecular construction) may likewise be employed in blood formation, they are never utilized by healthy individuals, who procure their entire supply from the nucleo-albumins. If we limit the most important sources of iron—the vegetables and the fruits—we cause a certain sluggishness of blood formation and an entire lack of reserve iron, such as is normally found in the liver, spleen, and bone marrow of healthy, well-nourished individuals. From the inappropriate selection of foods such persons acquire a predisposition to chlorosis. * * *
>
> The nutritive value of the green vegetables is indeed small when expressed in calories; they may be made exceedingly nutritious, however, by proper preparation with cream and butter. The nutritive value, however, is not to be considered only from the caloric standpoint. In addition to the material which is capable of oxidation, vegetables and fruits also contain many other substances which are useful and indispensable to the body—nutritive salts and iron compounds. We have never observed that vegetables and fruits decrease the capacity for the ingestion of other nutritive substances; on the contrary, the great variety which is offered makes it possible to increase the total supply of food.

There is also a tendency to begin the use of green vegetables with children at quite an early age. Thus, Huebner [b] stated at the Munich Congress of Physicians in 1896 that it had been found beneficial to give vegetables to young children, as, for instance, a small spoonful of cabbage, spinach, or something of the kind daily to children who have perhaps only eight teeth, the good results which attend such use of vegetables having been demonstrated in his practice as a physician.

---

[a] Nothnagel's Encyclopedia of Practical Medicine, Amer. Ed., 1905. (See article on chlorosis.)

[b] Bunge, Physiological and Pathological Chemistry. Philadelphia, 1902. 2. Eng. ed., p. 383.

IRON IN TYPICAL AMERICAN DIETARIES.

In a general consideration of the functions and desirable amounts of food-iron, it is important to take account of the amounts actually consumed by people of different occupations in different parts of the country. Using the data on iron in food materials which have been collected in connection with this investigation, it is possible to estimate with a fair degree of probability the amount of iron in any dietary in which the kinds and amounts of the foods are known, provided the food materials are mainly of the familiar staple sorts.

Two dietary studies carried on by the author as a part of his investigations on iron and nineteen others, selected as representative from among the many dietary studies made in various parts of the United States under the auspices of this Office, are given in the following pages (pp. 60–75), with the estimated amounts of iron furnished by the different food materials used in each case. The first of the studies made by the author for comparison with the dietary studies of professional men is summarized on pages 60–62, and the purpose of the other, an experimental dietary study, is explained in connection with the report of the experimental data on pages 62–64.

In the case of the two dietary studies not previously reported (Nos. 485 and 486) the full data regarding the food and nutrients consumed are recorded, as well as the amounts of iron supplied. In the case of the other studies full data regarding iron values are given, and details regarding food consumption are omitted, as the latter have been previously reported.

In discussing the results the data of the individual studies are considered in relation to protein content and fuel value, and finally the results of the different groups are compared with each other and with the data obtained in the experimental dietary described on page 76.

In calculating the amounts consumed per person per day in the dietary studies the conventional factors were used which show the relative amounts of food eaten by women and children as compared with men. These have been summarized in an earlier publication.[a]

In computing the results of the dietary studies made by the author data regarding food composition have in general been computed on the basis of average values for the composition of American food materials reported in a previous bulletin of this Office.[b] For dried Lima beans, data in an earlier publication[c] of this Office were used;

[a] U. S. Dept. Agr., Farmers' Bul. 142, p. 33.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, rev.

[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 11.

for wheat breakfast food, data in an Iowa Station bulletin,[a] and for grape jelly, data in a Connecticut State Station publication.[b]

The figures assumed in calculating the amounts of iron supplied by the food materials used in the dietary studies are derived from the data on pages 43–56, and are summarized in the following table:

TABLE 14.—*Proportion of iron in food materials.*

Food material.	Iron.	Food material.	Iron.
	Per cent.		*Per cent.*
Meats	(a)	Corn, dried	0.0029
Fish and shellfish	(a)	Cucumbers, as purchased	.0001
Eggs, edible portion	0.0030	Peas, fresh	.0015
Milk	.00024	Peas, dried	.0056
Cream	.0002	Peas, canned	.0008
Cheese	.0015	Potatoes, as purchased	.0010
Corn meal	.00115	Potatoes, edible portion	.00125
Oatmeal and other breakfast cereals	.0036	Spinach	.0030
Rice	.0008	Tomatoes, fresh or canned	.0004
Wheat breakfast food used in dietary study No. 486	.0057	Vegetable soup, canned, condensed	.0005
		Apples, fresh	.0003
Wheat flour, crackers, and macaroni	.0015	Apples, evaporated	.0014
Bread	.0010	Bananas, edible portion	.0008
Whole-wheat flour	.0020	Bananas, as purchased	.0005
Whole-wheat bread	.0013	Grapes	.0013
Green vegetables (asparagus, cabbage, celery, collards, greens, lettuce, onions, rhubarb)	.0008	Lemons, as purchased	.0001
		Oranges and lemons, edible portion	.0002
		Prunes, edible portion	.0029
Roots (beets, carrots, parsnips, radishes, sweet potatoes, turnips)	.0006	Prunes, as purchased	.0025
		Raisins	.0036
Pumpkins	.0006	Strawberries	.0009
Squash	.0006		
Beans, string	.0016	Canned and preserved fruit, jellies, jam	.0003
Beans, Lima, dried	.0072	Peanuts	.0020
Beans, pea, dried	.0067	Chocolate	.0020
Corn, canned	.0007		

[a] In meats 0.015 gram iron per 100 grams protein, and in fish and shellfish 0.005 gram iron per 100 grams protein.

DIETARY STUDIES IN PROFESSIONAL MEN'S FAMILIES.

DIETARY STUDY IN A TEACHER'S FAMILY IN NEW YORK (NO. 485).[c]

This study began with breakfast December 8, 1905, and covered ten days. The family consisted of 1 man, 3 women (one of whom was a colored servant at active muscular work), and a child 16 months old. The total number of meals taken was estimated as equivalent to the food consumption of one man at teacher's occupation for thirty-nine days. The food eaten furnished 102 grams of protein and 3,184 calories, at a cost of 29.4 cents per man per day.

[a] Iowa Sta. Bul. 74.

[b] Connecticut State Sta. Rpt. 1898, p. 108.

[c] This and similar numbers are the serial numbers used in recording the dietary studies made under the auspices of this Office.

The approximate weights of the different members of the family, the estimated degrees of muscular activity, and the number of meals eaten were as follows:

Food consumption of family reduced to equivalent of meals taken by head of family.

	Meals.
Man, weighing about 150 pounds, at mostly sedentary work	30.0
Woman, weighing about 145 pounds, at moderately active work (30 by 1)	30.0
Woman, weighing about 170 pounds, at active work (27 by 1.2)	32.4
Woman, weighing about 130 pounds, at light occupation (19 by 0.8)	15.2
Woman, weighing about 140 pounds, visitor (1 by 0.8)	.8
Child of 16 months, weighing about 24 pounds (30 by 0.3)	9.0
Total	117.4

Equivalent to meals of one man for thirty-nine days.

Table 15 shows the amount of the different foods eaten, the cost, and nutrients supplied, and Table 16 shows the estimated amount of iron supplied by the total food and the amount eaten per man per day.

TABLE 15.—*Weights and cost of food and nutrients in dietary study No. 485.*

Food consumed during entire study (ten days).		Cost, nutrients, and fuel value of food per man per day.				
Kind and amount.	Total cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.						
Beef: Steak, sirloin, 0.88 pound, 26 cents (2); roast, 3.73 pounds, 52 cents (1); corned, 5.12 pounds, 23 cents (4); smoked, 0.31 pound, 10 cents (3)	*Dollars.* 1.11	*Cents.* 2.9	*Grams.* 21	*Grams.* 21	*Grams.*	*Calories.* 271
Pork: Bacon, 0.63 pound, 17 cents (6); ham, salt, 0.31 pound, 10 cents (7); salt fat, 0.31 pound, 5 cents (5); lard, 1 pound, 13 cents (8)	.45	1.2	1	21	....	191
Fish: Cod, fresh, 1.25 pounds, 22 cents (9)	.22	.5	2	....	....	8
Eggs, 6.44 pounds, $1.83 (10)	1.83	4.7	10	7	....	102
Butter, 4.5 pounds, $1.30 (11)	1.30	3.3	1	45	....	404
Milk, 58 pounds, $2.35 (12)	2.35	6.0	22	27	34	464
Cheese, full cream, 1 pound, 20 cents (13)	.20	.5	3	4	....	48
Total animal food	7.46	19.1	60	125	34	1,488
VEGETABLE FOOD.						
Cereals: Cornmeal, 0.5 pound, 2 cents (14); hominy, 0.25 pound, 1 cent (15); oatmeal, 2 pounds, 10 cents, (16); rice, 0.12 pound, 1 cent (17); flour, wheat, 4.2 pounds, 19 cents (19); macaroni, 0.3 pound, 3 cents (20); bread, white, 15.7 pounds, 90 cents (21); crackers, soda, 0.8 pound, 13 cents (23); buns, 0.44 pound, 6 cents (24); sweet crackers, 0.2 pound, 5 cents (25); ginger snaps, 0.6 pound, 10 cents (26)	1.60	4.1	29	7	176	882
Sugar, etc.: Sugar, granulated, 5.72 pounds, 32 cents (27); molasses, 0.9 pound, 5 cents (28)	.37	.9	....	....	74	296
Vegetables. Beans, string, 2.13 pounds, 20 cents (29); beans, Lima, dried, 0.44 pound, 4 cents (30); beans, pea, dried, 0.94 pound, 5 cents (31); sweet corn, dried, 0.25 pound, 2 cents (32); lettuce, 0.56 pound, 10 cents (33); peas, dried, 0.2 pound, 1 cent (34); potatoes, white, 14.1 pounds, 37 cents (35); potatoes, sweet, 3 pounds, 12 cents (36); turnips, 3.8 pounds, 10 cents (37)	1.11	2.9	10	1	59	285

TABLE 15.—*Weights and cost of fooa, etc.*—Continued.

Food consumed during entire study (ten days).		Cost, nutrients, and fuel value of food per man per day.				
Kind and amount.	Total cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
VEGETABLE FOOD—continued.						
Fruits: Apples, 3.63 pounds, 20 cents (39); apples, evaporated, 0.5 pound, 6 cents (40); bananas, 2.35 pounds, 13 cents (41); oranges, 0.16 pound, 2 cents (42); prunes, dried, 1.25 pounds, 13 cents (43); raisins, 1.32 pounds, 20 cents (45); grape jelly, 0.88 pound, 9 cents (46)	*Dollars.* .83	*Cents.* 2.1	*Grams.* 3	*Grams.* 3	*Grams.* 44	*Calories.* 215
Miscellaneous: Chocolate, 0.15 pound, 4 cents (48); olive oil, 0.15 pound, 7 cents (49)	.11	.3	....	2	....	18
Total vegetable food	4.02	10.3	42	13	353	1,696
Total food eaten	11.48	[a]29.4	102	138	387	3,184

[a] Exclusive of the cost of coffee, condiments, etc., which was about 1 cent per man per day.

TABLE 16.—*Estimated amount of iron in dietary study No. 485.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Gram.*
Meat: Beef, edible portion, 4,550 grams; pork, edible portion, and lard, 1,020 grams (total meat protein, 860 grams)	0.129	Beans, Lima, dried, 200 grams	0.014
Codfish, fresh, edible portion, 567 grams (95 grams protein)	.005	Corn, sweet, dried, 115 grams	.003
Eggs, 2,920 grams	.079	Lettuce, edible portion, 255 grams	.001
Milk, 26,310 grams	.063	Peas, dried, 90 grams	.005
Butter, 2,040 grams	....	Potatoes, edible portion, 6,395 grams	.077
Cheese, 455 grams	.007	Sweet potatoes, edible portion, 1,360 grams; turnips, edible portion, 1,725 grams	.019
Bread, 7,120 grams; buns, 200 grams (as bread)	.073	Apples, edible portion, 1,645 grams	.005
Flour, 1,905 grams; crackers, 365 grams; cookies, 90 grams; ginger snaps, 270 grams; macaroni, 135 grams (as flour)	.042	Apples, evaporated, 225 grams	.003
Corn meal, 225 grams; hominy, 113 grams (as corn meal)	.004	Bananas, edible portion, 1,065 grams	.009
Oatmeal, 905 grams	.033	Orange, edible portion, 75 grams; grape jelly, 400 grams	.002
Rice, 55 grams; sugar, 2,595 grams; molasses, 410 grams	....	Prunes, as purchased, 565 grams	.014
Beans, string, edible portion, 965 grams	.015	Raisins, 600 grams	.022
Beans, pea, dried, 425 grams	.028	Chocolate, 65 grams	.001
		Olive oil, 70 grams	....
		In total food eaten	.653
		In food eaten per man per day	.017

DIETARY STUDY WITH A TEACHER IN NEW YORK (NO. 486).

This study was made with one man during fourteen days of January, 1906. The purpose was to determine whether it is feasible to obtain a palatable and satisfactory diet rich in iron without the use of meat, eggs, or expensive fruits and vegetables, and without employing unusual articles or combinations of food. The practical bearings of such an experiment are quite important. In the first place, it is desirable to test the somewhat common impression that in order to raise the iron content of the diet appreciably one must have recourse to the use of considerable quantities of lean meat, eggs, and spinach (or similar vegetables), all of which are often very expensive foods when considered with regard to the fuel value obtained for a given expenditure. This is, of course, especially true in cities. Fur-

thermore, the iron content of the food is of especial importance in the cases of growing persons and those who for any reason have become more or less anemic. In the dietaries of children it is desirable, as already explained (p. 58), to use lean meats as sparingly and vegetable foods as freely as is practicable; while in cases of anemia, both meats and eggs must often be restricted because of their tendency to favor intestinal putrefaction, which appears to be an important factor in many primary anemias. An extended investigation of this subject has been recently reported by Herter.[a] It is therefore a question of considerable importance whether, by the use of foods which tend to restrict putrefaction either directly or through increasing peristalsis, the body can be benefited with respect to intestinal conditions and at the same time supplied with an abundance of food-iron. In the experimental diet here recorded the food was chosen largely with respect to these considerations and with regard to the economy of the materials as sources of energy, as well as to the taste of the subject, who was accustomed to a diversified mixed diet. As a rule only such foods were used as furnish a fair return in calories for the cost. Milk, though furnishing comparatively little iron, was quite freely used in this dietary, and is believed to be especially important, partly because of its well-known tendency to reduce intestinal putrefaction and partly because its high calcium content appears to exert a favorable influence upon the utilization of iron in the body (see p. 38). The comparatively high cost of this experimental dietary and the small amount and variety of fresh vegetables are due partly to market conditions and partly to the fact that circumstances prevented the giving of adequate time or attention to the preparation of meals and compelled a free use of ready-prepared foods. The cost of the diet was therefore higher than would be the case had similar materials been purchased raw and prepared under ordinary conditions. The cost of food under these conditions was 28 cents per day, for which there were obtained and eaten 100 grams protein and 3,190 calories.

The iron content of this dietary was ascertained more accurately than in the preceding studies, determinations of iron being made in samples of all foods which furnished any important part of this element. Although, in order to reduce the amount of analytical work thus involved, the variety of foods used was rather restricted, the diet did not become monotonous or distasteful during the fourteen days covered by the study.

[a] Jour. Biol. Chem., 2 (1906), pp. 1–70.

The details of this dietary study follow:

TABLE 17.—*Weights and cost of food and nutrients in dietary study No. 486.*

Food consumed during entire study (14 days).		Cost, nutrients, and fuel value of food per man per day.				
Kind and amount.	Total cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Pork, salt, fat, 0.5 pound, 10 cents (5)	0.10	0.7	....	14	....	125
Milk, 33.5 pounds, $1.28 (12)	1.28	9.2	36	43	54	743
Butter, 0.66 pound, 20 cents (11)	.20	1.4	....	18	....	160
Lard, 0.6 pound, 8 cents (8)	.08	.6	....	20	....	178
Total animal food	1.66	11.9	36	95	54	1,206
VEGETABLE FOOD.						
Cereals: Wheat breakfast food, 3.41 pounds, 44 cents (18); bread, entire wheat, 7.31 pounds, 41 cents (22); crackers, soda, 0.68 pound, 11 cents (23)	.96	6.8	39	5	218	1,072
Vegetables: Beans, pea, dried, 1.5 pounds, 10 cents (31); potatoes, white, 2.63 pounds, 7 cents (35); soup, vegetable, canned, 1.38 pounds, 18 cents (38)	.35	2.5	14	1	45	245
Fruits, etc.: Apples, evaporated, 0.47 pound, 9 cents (40); bananas, 1.97 pounds, 15 cents (41); prunes, dried, 0.88 pound, 13 cents (44); raisins, 2.94 pounds, 39 cents (45); peanuts, 0.8 pound, 16 cents (47)	.92	6.6	11	14	124	665
Total vegetable food	2.23	15.9	64	20	387	1,982
Total food eaten	3.89	27.8	100	115	441	3,188

TABLE 18.—*Iron in dietary study No. 486.*

Kind and amount of food	Iron.	Kind and amount of food.	Iron.
	Gram.		*Gram.*
Milk, 15,196 grams	0.036	Apples, evaporated, 215 grams	0.003
Butter, 300 grams; lard, 270 grams; pork, clear fat, 227 grams	....	Bananas (edible portion), 895 grams	.007
Bread ("entire wheat"), 3,315 grams	.043	Prunes (edible portion), 400 grams	.012
Crackers, 310 grams	.005	Raisins, 1,335 grams	.048
Wheat breakfast food, 1,545 grams	.088	Peanuts (edible portion), 365 grams	.007
Beans, pea, dried, 680 grams	.046	In total food purchased and eaten	.313
Potatoes (edible portion), 1,195 grams	.014	In food eaten per man per day	.022
Soup, condensed vegetable, 625 grams	.004		

DIETARY STUDY OF A LAWYER'S FAMILY IN PITTSBURG (NO. 43).[a]

This study was made in the winter of 1895 in the family of a lawyer in comfortable circumstances, and continued thirty days. The family consisted of 2 men, 6 women, a girl 12 years old, and frequent visitors. The total number of meals taken was estimated as equivalent to those of one man for two hundred and twenty-seven days, and the total food eaten, calculated per man per day, furnished 91 grams of protein and 3,280 calories at a cost of 22.3 cents.

Table 19 shows the kinds and amounts of foods used, together with the estimated amount of iron furnished by each and by the diet as a whole.

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 52, p. 12.

The results are discussed further on in connection with those of the other dietary studies.

TABLE 19.—*Estimated amount of iron in dietary study No. 43.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Grams.		*Grams.*
Meats: Beef, 23,510 grams; veal, 6,390 grams; lamb, 9,605 grams; pork, 10,630 grams (total meat protein, 7,900 grams)	1.185	Beans, Lima, dried, 1,275 grams	0.092
Fish: Salmon, 1,215 grams (164 grams protein)	.008	Cabbage (edible portion), 1,930 grams; onions (edible portion), 535 grams; lettuce, 285 grams	.022
Eggs (edible portion), 10,775 grams	.324	Corn, canned, 1,825 grams	.013
Butter, 13,510 grams	....	Peas, canned, 5,175 grams	.041
Cheese, 625 grams	.009	Potatoes (edible portion), 35,855 grams	.448
Milk, 55,725 grams	.134	Sweet potatoes (edible portion), 3,795 grams	.023
Cream, 18,305 grams	.037	Tomatoes, canned, 6,045 grams	.024
Barley, 365 grams; buckwheat flour, 11,110 grams; macaroni, 340 grams; wheat, flour, 41,050 grams (as wheat flour)	.793	Oranges (edible portion), 2,440 grams; cranberries, 1,475 grams (as oranges)	.008
Corn meal, 3,940 grams	.045	Prunellas (as prunes), 905 grams	.023
Oatmeal (rolled oats), 3,090 grams	.111	Total	3.607
Rice, 1,520 grams	.012	Waste (estimated at 7 per cent)	.252
Bread, 5,105 grams	.051		
Sugar, 23,250 grams	....	In food actually eaten	3.355
Molasses, 3,175 grams	....	In food eaten per man per day	.015
Beans, dried, 3,035 grams	.203		

DIETARY STUDY OF A TEACHER'S FAMILY IN INDIANA (NO. 44).[a]

This study was made in March, 1895, and continued fourteen days. The family consisted of 4 men and 2 women. One of the men was a professor of mathematics, one an instructor in chemistry, the other two were college students. The younger woman was also a teacher. The total food consumed was equivalent to that of one man for seventy-eight days. The food eaten furnished 106 grams of protein and 2,780 calories, at a cost of 18 cents per man per day.

TABLE 20.—*Estimated amount of iron in dietary study No. 44.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Grams.*
Meats: Beef, 10,765 grams; veal, 6,600 grams; pork and lard, 2,950 grams. (Total meat protein, 3,413 grams)	0.512	Corn, canned, 1,210 grams	0.008
Eggs, 4,705 grams	.126	Potatoes (edible portion), 6,750 grams	.084
Butter, 1,785 grams	....	Parsnips, 795 grams; radishes, 310 grams	.007
Milk, 55,055 grams	.132	Apples (edible portion), 5,470 grams	.016
Mince meat, 370 grams	.004	Bananas (edible portion), 1,420 grams	.011
Corn meal, 2,395 grams; hominy, 255 grams (as corn meal)	.030	Oranges (edible portion), 540 grams; cranberries 355 grams (as oranges)	.002
Flour, 14,485 grams; crackers, 140 grams (as wheat flour)	.229	Prunes, dried, 440 grams; peaches, dried, 865 grams (as prunes)	.033
Oatmeal, 240 grams	.009	Raisins, 45 grams	.001
Sugar, granulated, 2,295 grams; sugar, "C," 4,310 grams; maple sirup, 895 grams; honey, 425 grams	....	In total food	1.300
Beans, dried, 835 grams	.056	In waste (estimated at 4.3 per cent)	.056
Cabbage, 2,890 grams; lettuce, 905 grams	.030	In food actually eaten	1.244
		In food eaten per man per day	.016

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 32, p. 12.

DIETARY STUDY OF A SCHOOL SUPERINTENDENT'S FAMILY IN CHICAGO (NO. 91).[a]

This study was made in April and May, 1895, and covered fourteen days. The family consisted of 1 man, 4 women (3 of whom were teachers), 2 children 2 and 8 years old, and occasional visitors. The total food consumed was equivalent to that of one man for seventy-five days. The food eaten per man per day furnished 123 grams protein and 3,260 calories, at a cost of 33.6 cents.

TABLE 21.—*Estimated amount of iron in dietary study No. 91.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Grams.*
Meat: Beef, 11,840 grams; veal, 4,540 grams; lamb, 3,280 grams; pork, 3,070 grams; chicken, 5,215 grams (total meat protein, 4,275 grams)	0.641	Beans, string, 1,130 grams	0.018
Fish, 2,040 grams (edible protein, 225 grams)	.011	Cucumbers, as purchased, 4,990 grams	.005
Eggs, 5,555 grams	.150	Peas, fresh, 1,475 grams	.022
Butter, 4,320 grams	......	Potatoes, as purchased, 27,215 grams	.272
Cheese, 455 grams	.008	Radishes, 455 grams	.003
Milk, 25,400 grams	.061	Tomatoes, 1,820 grams	.009
Cream, 3,175 grams	.006	Bananas, as purchased, 6,125 grams	.031
Corn meal, 2,710 grams	.031	Lemons, as purchased, 2,040 grams	.002
Flour, crackers, and macaroni, 16,785 grams	.252	Prunes, dried, 455 grams	.011
Sugar, 4,535 grams; molasses, 225 grams	......	Strawberries, 4,080 grams	.037
Asparagus, 340 grams; lettuce, 455 grams; onions, 455 grams	.010	In total food purchased[a]	1.580
		In food eaten per man per day (with no allowance for waste)	.021
		In food eaten per man per day (allowing 10 per cent for waste)	.019

[a] In this study no account was taken of waste, which was therefore presumably not large. The usual corrections are applied for the average amounts of inedible material in the foods as purchased.

DIETARY STUDIES OF COLLEGE STUDENTS' CLUBS.

DIETARY STUDY OF A STUDENTS' CLUB, UNIVERSITY OF TENNESSEE (NO. 207).[b]

This study was made during fourteen days in November, 1896, in a university boarding club. The group consisted of 90 men (2 professors, 87 students, and a servant), 9 women, of whom 5 were servants, and 1 child 10 years of age. The total food consumption was equivalent to that of one man for one thousand two hundred and seventy-eight days. The food eaten per man per day furnished 123 grams protein and 3,595 calories, at a cost of 18.1 cents.

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 55, p. 66.

[b] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 53, p. 19.

TABLE 22.—*Estimated amount of iron in dietary study No. 207.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Grams.		*Grams.*
Meat: Beef, 449.8 kilograms; veal, 74.5 kilograms; pork, 54.6 kilograms; fowl, 14.8 kilograms; (total meat protein, 81 kilograms)	12.165	Potatoes, edible portion, 134.3 kilograms.	1.677
Fish: Catfish, 22.7 kilograms; salmon, canned, 16.4 kilograms (total fish protein, 6.6 kilograms)	.330	Sweet potatoes, edible portion, 87.2 kilograms; turnips, 24.5 kilograms	.670
Eggs, 56.05 kilograms	1.513	Corn, canned, 8.6 kilograms	.060
Butter, 75.64 kilograms	....	Tomatoes, pickles, and chowchow, 65.9 kilograms (as tomatoes)	.330
Milk, 636.1 kilograms	1.527	Apples, edible portion, 98.5 kilograms; cranberries, 4.8 kilograms	.310
Corn meal, corn-meal grits, and hominy, 57.3 kilograms	.659	Bananas, 5.1 kilograms	.041
Oatmeal and graham flour, 49.8 kilograms (as oatmeal)	1.793	Prunes, as purchased, 7.37 kilograms; figs, 5.50 kilograms; dried currants, 0.68 kilogram	.339
Rice, 10.7 kilograms	.085	Grapes, edible portion, 18.4 kilograms	.239
Wheat flour and crackers, 189.3 kilograms	2.840	Canned pears and peaches, 24.8 kilograms	.074
Bread, 50.2 kilograms	.502	Evaporated pears, apricots, and peaches (as evaporated apples), 10 kilograms	.150
Chocolate, 1.47 kilograms	.029	In total food purchased	25.978
Sugar, 164.4 kilograms; molasses, 36.3 kilograms; cornstarch and tapioca, 4.8 kilograms	....	In waste (7 per cent)	1.818
Beans, dried, 6.35 kilograms	.425	In total food eaten	24.160
Cabbage and celery, 26.2 kilograms; lettuce, 11.7 kilograms	.303	In food eaten per man per day	.019

DIETARY STUDY OF WOMEN STUDENTS, PAINESVILLE, OHIO (NO. 323).[a]

This study covered ten days of January, 1900. The group studied consisted of 115 women, of whom 20 were instructors, 91 students, and 4 servants. The total meals taken were equivalent to the food of one woman for one thousand and forty-nine days. "The attempt was made to regulate the diet in such a way that it should not exceed a definite cost and at the same time please the students." The food eaten per woman per day furnished on an average 68 grams protein and 2,665 calories, at a cost of 18.3 cents.

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 91, p. 27.

TABLE 23.—*Estimated amount of iron in dietary study No. 323.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Grams.		*Grams.*
Meat: Beef, 98.7 kilograms; mutton, 25.4 kilograms; pork, 48.9 kilograms; chicken, 19.5 kilograms. (Total meat protein, 33.60 kilograms)	5.040	Beans, Lima, dried, 4.9 kilograms	0.353
Fish: Salt cod, 12.7 kilograms; oysters, 8.3 kilograms; (total fish protein, 1.06 kilograms)	.053	Beans, navy, dried, 6.7 kilograms	.449
Eggs, 13 kilograms	.351	Cabbage, 4.5 kilograms	.041
Butter, 60.5 kilograms	....	Peas, canned, 10.3 kilograms; dried, 2 kilograms	.194
Cheese, 5.78 kilograms	.088	Potatoes, as purchased, 139 kilograms	1.390
Cream, 5.45 kilograms	.011	Spinach, 5.14 kilograms	.154
Milk, 322.7 kilograms	.775	Tomatoes, 11.1 kilograms; cucumber pickles, 4.3 kilograms	.062
Corn meal and hominy, 14.5 kilograms	.167	Apples, 44.3 kilograms; apricots, 5.2 kilograms (as apples)	.149
Wheat breakfast food, 15.1 kilograms; graham flour, 33.7 kilograms (as oatmeal)	1.757	Apple butter, canned cherries, cranberry sauce, raspberry jam, 36.5 kilograms	.110
Rice, 7 kilograms	.560	Bananas, 30 kilograms	.150
Whole wheat flour, 3.27 kilograms	.065	Raisins, 0.68 kilogram	.024
Wheat flour, 140.4 kilograms; crackers, 1.6 kilograms	2.130	Prunes, dates, and figs (as prunes), 15 kilograms	.375
Sugar, 74.9 kilograms; molasses and sirup, 14.5 kilograms; cornstarch, 0.82 kilogram; tapioca, 1.82 kilograms	....	Oranges and lemons (as oranges), 70.9 kilograms	.142
Chocolate, 1.10 kilograms	.022	In total food	14.135
Beets, 14.1 kilograms; parsnips, 15.9 kilograms; turnips, 14.5 kilograms; sweet potatoes, 16.6 kilograms; squash, 16.8 kilograms	.623	In waste (estimated at 13 per cent)	1.938
		In food eaten	12.197
		In food eaten per woman per day	.012
		Estimated equivalent per man per day	.015

DIETARY STUDIES OF MECHANICS' AND INDOOR LABORERS' FAMILIES.

DIETARY STUDY OF A CARPET DYER'S FAMILY IN NEW YORK CITY (NO. 35).[a]

This study was made in April and May, 1895, and covered ten days. The group consisted of the family and 3 boarders and included 4 men, 1 woman, 3 boys, aged 12, 7, and 3 years, and 6 girls, aged 14, 11, 6, 4, and 2 years, and 8 months. The woman did sewing, and the 14-year-old girl did the marketing and housekeeping. The total of meals taken was computed by the usual factors as equivalent to the meals of one man for ninety-two days. The food eaten cost 16 cents and furnished 71 grams of protein and 2,430 calories per man per day.

TABLE 24.—*Estimated amount of iron in dietary study No. 35.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Grams.		*Grams.*
Meat: Beef, 9,215 grams; pork, 8,480 grams; chicken, 2,495 grams (total meat protein, 2,685 grams)	0.403	Rice, 410 grams	0.003
Fish: Cod, fresh, 905 grams; salmon, canned, 905 grams; sardines, canned, 455 grams (total fish protein, 400 grams)	.020	Tapioca, 455 grams; sugar, 6,850 grams	....
Eggs, edible portion, 3,445 grams	.103	Cabbage sprouts, onions, and soup greens, 4,705 grams	.038
Butter, 3,630 grams	....	Potatoes, edible portion, 12,770 grams	.153
Cheese, 410 grams	.006	Plums (canned) and jam, 800 grams	.002
Milk, 11,725 grams	.028	Prunes, 680 grams	.017
Condensed milk, 455 grams	.002	Raisins, 455 grams	.016
Oatmeal (and barley), 2,040 grams	.073	In total food	1.142
Wheat flour, crackers, and macaroni, 2,635 grams	.040	In waste (1.2 per cent)	.014
Bread, 23,845 grams	.238	In food actually eaten	1.128
		In food eaten per man per day	.012

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 46, pp. 23, 78.

DIETARY STUDY OF A TIN ROOFER'S FAMILY IN NEW YORK CITY (NO. 112).[a]

This study was made during eleven days in November, 1895. The group comprised the family proper and three boarders. It was considered a typical Irish-American family. There were included in the study five men and four women (the son and daughters being grown). The total meals taken were equivalent to the meals of one man for ninety-three days. The food purchased, which was all eaten, furnished per man per day 84 grams of protein and 2,335 calories at a cost of 16 cents.

TABLE 25.—*Estimated amount of iron in dietary study No. 112.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Grams.*
Meat: Beef, 15,190 grams; pork, 13,350 grams (total meat protein, 4,170 grams)	0.625	Sugar, 5,615 grams	....
Fish: Fresh cod, 905 grams; salt cod, 680 grams (total fish protein, 205 grams)	.010	Cabbage (edible portion) and onions, 7,650 grams	0.061
Eggs, 3,285 grams	.089	Corn, canned, 910 grams	.006
Butter, 3,200 grams	.....	Peas, canned, 905 grams	.007
Milk, 14,235 grams	.034	Potatoes (as purchased), 21,800 grams	.218
Oatmeal, 905 grams	.033	In total food purchased and eaten	1.260
Rice, 230 grams	.002	In food eaten per man per day	.014
Bread, 17,500 grams	.175		

DIETARY STUDY OF A SEWING WOMAN'S FAMILY IN NEW YORK CITY (NO. 48).[b]

This study was made during seven days of June, 1895. The family consisted of the mother, five sons, aged 14, 11, 8, 4, and 3 years, and one daughter, 6 years old. The total food consumption was equivalent to that of one man for twenty-eight days. The income of the family was only $30 to $40 a month, of which $10 was paid for rent. As the mother was the principal wage-earner, it was impossible to give much time to the purchasing and preparation of the food. The cost per person per day was less than 6 cents; calculated per man per day, 9 cents. The food eaten furnished per man per day 54 grams of protein and 1,500 calories.

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 46, pp. 33, 86.

[b] Ibid., pp. 59, 109.

TABLE 26.—*Estimated amount of iron in dietary study No. 48.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Gram.*
Meat: Beef, 455 grams; pork, 905 grams (total meat protein, 170 grams)	0.026	Beans, dry, 905 grams	0.061
Fish: Sardines, 230 grams (protein, 58 grams)	.003	Potatoes, 1,815 grams	.018
Eggs, 1,625 grams	.044	Radishes, 285 grams	.002
Butter, 225 grams	....	Rhubarb, 180 grams	.001
Milk, 8,390 grams	.020	Tomatoes, canned, 1,135 grams	.006
Barley (as oatmeal), 340 grams	.012	In total food purchased	.257
Bread, rolls, and cakes, 3,685 grams	.037	In waste (6 per cent)	.015
Flour and crackers, 1,815 grams	.027	In food actually eaten	.242
Sugar, 1,735 grams	....	In food eaten per man per day	.009

DIETARY STUDY OF A HOUSE DECORATOR'S FAMILY IN PITTSBURG (NO. 190).[a]

This study was made during thirty days in January and February, 1897, in a family consisting of 1 man, 1 woman, a girl of 15, and 2 boys, 12 and 2 years old. The meals taken were estimated as equivalent to those of one man for ninety-six days. The income was estimated at $84 per month, and as the result of good management in the marketing a considerable variety of both animal and vegetable foods was obtained. The food eaten furnished per man per day 112 grams of protein and 3,305 calories, at a cost of 19.6 cents.

TABLE 27.—*Estimated amount of iron in dietary study No. 190.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Grams.*
Meat: Beef, 13,875 grams; veal, 4,430 grams; lamb, 1,060 grams; pork, 14,615 grams (total meat protein, 5,495 grams)	0.824	Corn, canned, 1,770 grams	0.012
Oysters, 595 grams (protein, 36 grams)	.002	Peas, canned, 595 grams	.005
Eggs, 1,875 grams	.050	Pickles and catsup (as tomatoes), 1,065 grams	.005
Butter, 2,995 grams	....	Potatoes (edible portion), 21,625 grams	.270
Milk, 32,590 grams	.078	Apples, 22,985 grams	.069
Barley (as oatmeal), 285 grams	.010	Bananas (edible portion), 2,730 grams	.022
Corn meal, 940 grams	.011	Oranges and lemons, 1,270 grams	.002
Wheat flour and crackers, 19,680 grams	.295	Canned peaches and plum butter, 5,255 grams	.016
Rice, 255 grams	.002	Total	1.930
Bread and cake, 5,245 grams	.052	In waste (3.2 per cent)	.060
Beans, dried, 1,375 grams	.092	In food eaten	1.870
Beets, sweet potatoes, and turnips (edible portion), 9,130 grams	.064	In food eaten per man per day	.019
Cabbage, onions, soup greens, sauerkraut (edible portion), 7,545 grams	.059		

DIETARY STUDY OF A GLASS BLOWER'S FAMILY IN PITTSBURG (NO. 191).[b]

This study was made in a family of adults—4 men and 3 women—in January and February, 1897, and covered thirty-one days, during

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 52, p. 31.

[b] Ibid., p. 35.

which the total number of meals taken was equivalent to the meals of one man for one hundred and eighty-six days. Two of the men were idle at the time of the study. The food eaten furnished per man per day 94 grams of protein and 3,085 calories, at a cost of 16 cents.

TABLE 28.—*Estimated amount of iron in dietary study No. 191.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Grams.		*Grams.*
Meat: Beef, 34,745 grams; veal, 765 grams; lamb, 435 grams; pork, 15,060 grams; chicken, 2,935 grams (total meat protein, 8,537 grams)	1.281	Potatoes, edible portion, 34,350 grams	0.429
Fish, 2,090 grams (protein, 287 grams)	.014	Sweet potatoes and turnips (18 edible portion), 7,330 grams	.044
Eggs, 3,995 grams	.108	Tomatoes (canned), catsup, pickles, vegetable soup, 10,825 grams	.043
Butter, 6,675 grams	.....	Apples, 18,780 grams	.056
Milk, 23,865 grams	.057	Bananas, 780 grams	.006
Cottage cheese, 2,520 grams	.008	Figs and dried peaches (as evaporated apples), 835 grams	.013
Corn meal, 1,375 grams	.016	Jelly, jam, and fruit butter, 4,140 grams	.012
Flour and crackers, 40,960 grams	.614	In total food purchased	2.975
Oats, rolled, 880 grams	.032	In waste (0.7 per cent)	.020
Rice, 555 grams	.004	In food actually eaten	2.955
Bread and cake, 9,765 grams	.098	In food eaten per man per day	.016
Sugar, 18,345 grams; cornstarch, 40 grams	.....		
Beans, dried Lima, 1,300 grams	.094		
Corn, canned, 625 grams	.004		
Celery, onions, and sauerkraut, 5,360 grams	.042		

DIETARY STUDY OF A MILL WORKMAN'S FAMILY IN PITTSBURG (NO. 128).[a]

This study was made during twenty-nine days of January and February, 1896, in a family consisting of 2 men, 1 woman, 2 girls aged 16 and 6, and 3 boys aged 13, 10, and 8 years, respectively, the total food eaten being equivalent to the meals of one man for one hundred and sixty-seven days. This family was taken as representative of a large class of poor foreign laborers in Pittsburg. The food eaten, calculated per man per day, cost 13 cents, and furnished 83 grams of protein and 2,525 calories.

TABLE 29.—*Estimated amount of iron in dietary study No. 128.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Grams.*
Meat: Beef, 17,700 grams; pork, 17,095 grams (total meat protein, 5,685 grams)	0.853	Peas, dried, 115 grams	0.006
Fish: Herring (boneless, smoked), 1,460 grams; salmon (canned), 855 grams (total fish protein, 708 grams)	.035	Onions, 1,205 grams	.010
Eggs, without shell, 2,735 grams	.082	Potatoes, edible portion, 48,335 grams	.508
Butter, 5,480 grams	.....	Tomatoes (canned) and catsup, 1,835 grams	.009
Cheese, 740 grams	.011	Apples, 1,020 grams	.003
Milk, 19,305 grams	.046	Jam, 570 grams	.002
Oatmeal and barley, 710 grams	.025	Prunes, 400 grams	.010
Flour, 2,555 grams	.038	In total food purchased	2.291
Rice, 455 grams	.004	In waste (1.8 per cent)	.040
Bread, cake, and pie, 49,545 grams	.495	In food actually eaten	2.251
Sugar, 8,210 grams; molasses, 1,755 grams	.....	In food eaten per man per day	.013
Beans, dried, 2,350 grams	.157		

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 52, p. 18.

DIETARY STUDY OF A MILL WORKMAN'S FAMILY IN PITTSBURG (NO. 129).[a]

This study was begun in January, 1896, and continued twenty-nine days. The family consisted of 2 men, 2 women, and 5 children, aged, respectively, 13, 10, 7, and 4 years, and 7 months. The family was in very poor circumstances. The total number of meals taken was calculated by the usual factors as equivalent to the meals of one man for one hundred and seventy-four days. The food furnished per man per day 77 grams protein and 2,440 calories, at a cost of 8.7 cents.

TABLE 30.—*Estimated amount of iron in dietary study No. 129.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Gram.*
Meat: Beef, 13,880 grams; pork, 20,230 grams (total meat protein, 5,350 grams)	0.803	Cabbage, celery, onions, water cress, 8,350 grams	0.067
Oysters, 525 grams (32 grams protein)	.002	Carrots, parsnips, ruta-bagas (edible portion), 3,505 grams	.018
Butterine, 3,910 grams	....	Potatoes (edible portion), 21,215 grams	.265
Cheese, 1,860 grams	.028	Apples, and apple jelly, 2,080 grams	.006
Milk, 14,745 grams	.035		
Flour, 9,810 grams	.147		
Rolled oats, 285 grams	.010	In total food purchased	2.074
Bread, cake, pie, and rolls, 55,795 grams	.558	In waste (0.6 per cent)	.012
Sugar, 10,455 grams	....		
Beans, dried, 580 grams	.039	In food actually eaten	2.062
Beans, Lima, dried, 1,330 grams	.096	In food eaten per man per day	.012

DIETARY STUDY OF A MECHANIC'S FAMILY IN KNOXVILLE, TENN. (NO. 181).[b]

The family here studied consisted of 1 man, 2 women, and a boy 11 years old. The man was an engineer at hard work. The study covered fourteen days in February, 1896. The total number of meals taken was equivalent to the food of one man for forty-eight days. The food eaten furnished per man per day 97 grams of protein and 4,060 calories, at a cost of 12 cents.

TABLE 31.—*Estimated amount of iron in dietary study No. 181.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Gram.*
Pork (including lard), 14,225 grams; chicken, 1,815 grams (total meat protein, 1,380 grams)	0.207	Onions, 680 grams; turnip greens, 3,630 grams	0.034
Butter, 1,590 grams	....	Potatoes (edible portion), 8,255 grams	.103
Buttermilk (as milk), 9,070 grams	.022	Fruit jelly, 1,700 grams	.005
Eggs, 1,135 grams	.031	In total food purchased	.885
Corn meal, 14,720 grams	.169	In waste (8.6 per cent)	.076
Flour, 9,410 grams	.141		
Sugar, 455 grams	....	In food actually eaten	.809
Beans, dried, 1,815 grams	.122	In food eaten per man per day	.017
Peas, dried, 905 grams	.051		

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations, Bul. 52, p. 22.

[b] Ibid., Bul. 53, p. 15.

DIETARY STUDIES OF FARMERS' FAMILIES AND OUTDOOR LABORERS.

DIETARY STUDY OF MAINE LUMBERMEN (NO. 391).[a]

This study was begun in January, 1902, and continued sixteen days. The group included 30 men, most of whom were engaged in severe outdoor labor. The total number of meals taken was equivalent to the meals of one man for four hundred and ninety-two days. The food eaten furnished per man per day 179 grams of protein and 6,780 calories, at a cost of 23.6 cents.

TABLE 32.—*Estimated amount of iron in dietary study No. 391.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Grams.		*Grams.*
Meat: Beef, 220 kilograms; pork and sausage, 61 kilograms (total meat protein, 35.2 kilograms)	5.280	Carrots and turnips, 34.1 kilograms	0.205
Fish: Cod, 15.9 kilograms; mackerel, 20 kilograms; salmon, 20 kilograms (total fish protein, 9 kilograms)	.450	Peas, dried, 4.5 kilograms	.248
Butter, 20.9 kilograms	....	Potatoes, 78 kilograms	.780
Condensed milk, 1.4 kilograms	.008	Onions, 0.2 kilogram	.002
Lard compound, 64.8 kilograms	....	Dried apples, 18.4 kilograms	.276
Corn meal, 5.7 kilograms	.066	Prunes, 28 kilograms	.700
Oatmeal, 0.9 kilogram	.032	Raisins, 4.5 kilograms	.162
Rice, 3.6 kilograms	.029	Currant and strawberry jelly, 15.9 kilograms	.048
Flour, 173.6 kilograms	2.607	In total food purchased	17.700
Sugar, 63 kilograms; molasses, 68.2 kilograms	....	In waste (3 per cent)	.531
Beans, dried, 101.6 kilograms	6.807	In food actually eaten	17.169
		In food eaten per man per day	.035

DIETARY STUDY OF A FARMER'S FAMILY IN CONNECTICUT (NO. 45.)[b]

This study was made in December, 1894, and continued seven days. The family consisted of 2 men, 1 woman, a boy 7 years old, a girl 4 years old, and a child under 2 years. The total number of meals taken was equivalent to the meals of one man for twenty-seven days. The food furnished 108 grams protein and 3,755 calories per man per day.

TABLE 33.—*Estimated amount of iron in dietary study No. 45.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Gram.*
Meat: Beef, 1,700 grams; lard, 738 grams; chicken, 2,290 grams (total meat protein, 671 grams)	0.101	Potatoes, edible portion, 8,095 grams	0.101
Milk, 9,000 grams	.022	Pumpkins, squash, sweet potatoes, and turnips, 13,155 grams	.079
Butter, 455 grams	....	Apples, edible portion, 13,260 grams	.040
Flour, 12,700 grams	.190	In total food eaten	.562
Sugar, 2,040 grams	....	In food eaten per man per day	.021
Cabbage, edible portion, 3,630 grams	.029		

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 149, p. 17.

[b] For full data regarding the amount and composition of the food eaten, see Connecticut Storrs Sta. Rpt. 1895, p. 148.

DIETARY STUDY OF A FARMER AND MECHANIC'S FAMILY IN TENNESSEE (NO. 182).[a]

This study was made during fourteen days in March, 1896, in a family consisting of 3 men and 3 women, the total meals taken being equivalent to the meals of one man for sixty-six days. The food eaten furnished 95 grams of protein and 2,820 calories at a cost of 19 cents per man per day.

TABLE 34.—*Estimated amount of iron in dietary study No. 182.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Grams.		*Grams.*
Meat: Beef, 1,810 grams; pork, 15,780 grams (total meat protein, 2,250 grams).	0.338	Cabbage, 1,360 grams	0.011
Fish, 2,035 grams (edible protein, 279 grams)	.014	Corn, canned, 7,470 grams	.052
Eggs, 5,605 grams	.151	Parsnips, 1,020 grams	.006
Butter, 1,980 grams	....	Potatoes (edible portion), 20,035 grams	.250
Milk and buttermilk, 16,950 grams	.041	Tomatoes, canned, 765 grams	.004
Flour and crackers, 10,525 grams	.158	Raisins, 285 grams	.010
Oatmeal, 2,435 grams	.088	Canned huckleberries, 6,705 grams	.020
Rice, 565 grams	.004	In total food eaten	1.395
Sugar, 1,130 grams; maple sirup, 680 grams; tapioca, 115 grams	....	In waste (10 per cent)	.139
Beans, dried, 3,705 grams	.248	In food actually eaten	1.256
		In food eaten per man per day	.019

DIETARY STUDY OF FARM STUDENTS AT KNOXVILLE, TENN. (NO. 208).[b]

The group included in this study consisted of 13 men whose ages averaged 25.4 years, 5 women whose average age was 32 years, and 1 child 7 years old. The study covered fourteen days in December, 1896, the total meals taken being equivalent to the meals of one man for one hundred and fifty-five days. The rate of board was $2 per week. The food actually eaten per man per day furnished 66 grams of protein and 3,560 calories at a cost of 15 cents.

TABLE 35.—*Estimated amount of iron in dietary study No. 208.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Grams.		*Grams.*
Meat: Beef, 2,610 grams; pork and lard, 25,465 grams; fowl, 4,280 grams (total meat protein, 2,470 grams)	0.371	Potatoes (edible portion), 19,730 grams	0.247
Eggs, 1,995 grams	.054	Sweet potatoes, radishes, and turnips (edible portion), 5,400 grams	.032
Butter, 7,005 grams	....	Apples (edible portion), 6,720 grams	.020
Milk and buttermilk, 26,820 grams	.064	Grapes, cranberries, and blackberries (as grapes), 5,590 grams	.073
Corn meal and grits, 6,150 grams	.071	Preserved plums, 5,870 grams	.015
Flour and crackers, 46,490 grams	.697		
Oatmeal, 3,005 grams	.108	In total food purchased	1.887
Rice, 3,400 grams	.027	In waste (8.6 per cent)	.162
Bread and cake, 5,390 grams	.054		
Sugar, 12,930 grams; molasses, 1,390 grams	....	In food actually eaten	1.725
Cabbage, celery, and onions, 6,380 grams	.051	In food eaten per man per day	.011

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul. 53, p. 16.

[b] Ibid., p. 21.

DIETARY STUDY OF A NEGRO FARMER'S FAMILY IN ALABAMA (NO. 139).[a]

This family consisted of 1 man and 1 woman. The study was begun in January, 1896, and continued sixteen days. The food taken was estimated to be equivalent to the meals of one man twenty-nine days. The man and wife lived in a one-room log cabin and worked a 25-acre farm, which was part of a large plantation about 7 miles from Tuskegee. They were in more comfortable circumstances than most negro farmers of the region. They expended for food about 10 cents per man per day and obtained (on the same basis) 80 grams of protein and 4,955 calories.

TABLE 36.—*Estimated amounts of iron in dietary study No. 139.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Gram.*
Meat: Pork, bacon, and lard, 10,435 grams (containing 683 grams protein)	0.102	Sugar, 1,030 grams	
Milk, 1,020 grams	.002	Sweet potatoes, 1,985 grams	0.012
Corn meal, 13,610 grams	.156	Total food	.356
Flour, 5,245 grams	.079	Per man per day	.012
Rice, 595 grams	.005		

DIETARY STUDY OF A NEGRO FARMER'S FAMILY IN ALABAMA (NO. 100).[b]

This study was made at the same time and in the same region as the one preceding. The family consisted of a man and wife and 5 children, the eldest of whom was 11 years old; total consumption of food being equivalent to one man fifty-nine days. The food furnished 44 grams of protein and 2,240 calories at a cost of 3 cents per man per day.

TABLE 37.—*Estimated amounts of iron in dietary study No. 100.*

Kind and amount of food.	Iron.	Kind and amount of food.	Iron.
	Gram.		*Gram.*
Meat: Bacon and lard, 3,035 grams (containing 131 grams protein)	0.020	Collards (cabbage), 255 grams	0.002
Flour, 9,470 grams	.142	In total food purchased and eaten	.410
Corn meal, 20,920 grams	.240	In food eaten per man per day	.007
Rice, 710 grams	.006		

[a] For full data regarding the amount and composition of the food eaten, see U. S. Dept. Agr., Office of Experiment Stations Bul 38, p. 56.

[b] Ibid., p. 28.

SUMMARY OF THE DIETARY STUDIES.

The following table summarizes the principal data in the American dietaries regarded as typical and in the experimental study made in New York:

TABLE 38.—*Summary of estimated amounts of iron in typical American dietaries.*

Description and number of dietary study.	Iron per man per per day.	Protein per man per day.	Fuel value per man per day.	Cost per man per day.	Iron per 100 grams protein.	Iron per 3,000 calories.
Professional men's families and college students' clubs.						
	Mgs.	*Grams.*	*Calories.*	*Cents.*	*Mgs.*	*Mgs.*
Lawyer's family (Pittsburg) No. 43	15	91	3,280	22	16	14
Teacher's family (Indiana) No. 44	16	106	2,780	18	15	17
School superintendent's family (Chicago) No. 91	21	123	3,260	34	17	19
Teacher's family (New York City) No. 485	17	102	3,180	29	17	16
Students' club (University of Tennessee) No. 207	19	123	3,595	18	15	16
Women students' club (Ohio) No. 323	15	85	3,230	22	18	14
Mechanics' and indoor laborers' families.						
Carpet dyer's family (New York City) No. 35	12	71	2,430	16	17	15
Tin roofer's family (New York City) No. 112	14	84	2,335	16	17	18
Sewing woman's family (New York City) No. 48	9	54	1,500	9	17	18
House decorator's family (Pittsburg) No. 190	19	112	3,305	20	17	18
Glass blower's family (Pittsburg) No. 191	16	94	3,085	16	17	15
Mill workman's family (Pittsburg) No. 128	13	83	2,525	13	16	16
Mill workman's family (Pittsburg) No. 129	12	77	2,440	9	15	15
Mechanic's family (Tennessee) No. 181	17	97	4,060	12	17	12
Farmers' families and outdoor laborers.						
Lumbermen (Maine) No. 391	35	179	6,780	24	20	15
Farmer's family (Connecticut) No. 45	21	108	3,755	(?)	20	17
Farmer's and mechanic's family (Tennessee) No. 182	19	95	2,820	19	20	20
Farm students' club (Tennessee) No. 208	11	66	3,560	15	17	9
Negro farmer's family (Alabama) No. 139	12	80	4,955	10	15	7
Negro farmer's family (Alabama) No. 100	7	44	2,240	3	16	9
Experimental dietary study.						
Teacher (New York City) No. 486	22	100	3,190	28	22	21

DISCUSSION OF RESULTS OF DIETARY STUDIES.

The estimated amounts of iron in the twenty typical dietaries range from a minimum of 7 milligrams to a maximum of 35 milligrams per man per day. While this is a very striking difference, the highest amount being five times the lowest, it is only slightly greater than the corresponding difference in the protein content of the same dietaries, viz, 44 grams of protein in the dietary with the lowest, as against 179 grams in that with the highest iron. In fact, the most noticeable relation to be observed in comparing the results of the twenty studies is that the amounts of iron and protein run approximately parallel throughout, there being but slight variation in the figures in the column showing iron per 100 grams of protein.

Among the six studies of professional men's families and college students' clubs the amount of iron ranges from 14 to 21 milligrams,

of protein from 85 to 123 grams, and the fuel value from 2,780 to 3,595 calories. Here the iron as a rule varies approximately with the protein, the ratio of iron to protein being more nearly constant than that of iron to calories.

The same is true of the relation of iron to protein and to fuel value in the eight studies of mechanics' and indoor laborers' families, where the amounts of iron and protein and the fuel values show greater variations and somewhat lower averages.

Among the professional men's families and students' clubs there is no apparent connection between the cost of the dietaries and the amounts either of iron or of protein and energy obtained, because the studies cover such a wide range of locality and market conditions that any attempt to compare the purchasing power of a given sum in the different dietaries would almost certainly be misleading. Among the studies of mechanics' and city laborers' families, however, there are two groups (one of three in New York City and another of four in Pittsburg), in each of which the market conditions were apparently fairly uniform for the different families of the group, so that the results afford some data for a consideration of the relations of the iron content of the dietary to its cost. In dietary studies No. 35 and No. 112 the cost was the same, and the difference in selection of food materials gave a higher fuel value, but lower protein and iron content, to the former diet than to the latter. In the case of the sewing woman's family (dietary No. 48) poverty compelled the adoption of a very limited dietary, in which the amounts of iron, protein, and energy are all below the usual standards, but the ratios of iron to protein and iron to calories are the same here as in the case of dietary study No. 112, where the expenditure for food was nearly twice as great. The four studies of this group made in Pittsburg also illustrate the relation of cost to iron and other nutrients under similar market conditions. As the amount expended for food decreases from 20 cents to 9 cents a day there is a corresponding decrease in iron content from 19 to 12 milligrams, in protein from 112 to 77 grams, and in fuel value from 3,305 to 2,440 calories. The ratio of iron to protein and to energy is nevertheless nearly the same for all four dietaries. Three of the eight studies in this group indicate less iron than appears to be desirable in families where there are growing children, but the protein and energy are also low in these cases, the general deficiency of the dietary being primarily due to poverty, although greater knowledge and thrift in the selection of food would of course have permitted some improvement without increase of expenditure.

The group including the dietaries of farmers and outdoor laborers shows much greater variation than either of the others, doubtless because it embraces much greater extremes of locality, climate, activ-

ity, local food habits, and financial conditions. Here, as with the preceding groups, the iron varies with the protein and to a slightly greater extent, while the variations in fuel value are much smaller.

Among the professional men's, mechanics', and city laborers' families the only cases in which there appears to have been a deficiency of iron are those in which the entire diet was very limited as the result of poverty and inability to give adequate attention to the purchase and preparation of food. On the other hand, at the farm students' club in Tennessee and among the negro farmers in Alabama there appears to have been a deliberate selection of food low in protein and iron as compared with fats and carbohydrates. The estimated amount of iron in dietary No. 100 is less than has been found necessary for the maintenance of equilibrium in carefully conducted metabolism experiments. It is possible that at other times than during the periods of observation these negro families may have consumed considerable amounts of iron in the form of pot herbs or "greens," which could probably have been obtained without expense during certain seasons. If we assume that the studies recorded fairly represent the dietary habits of these people throughout the year, it is evident that they are able to maintain equilibrium with smaller amounts of food-iron than are the men who have served as subjects for the metabolism experiments conducted by Stockman in Scotland, by von Wendt in Sweden, and in the investigations here reported.

In the experimental dietary in which the food, with the exception of milk, was almost entirely of vegetable origin, both the absolute and the relative amount of iron consumed per man per day were higher than in any of the family dietaries. Though, of course, not so high in actual amount as in the lumbermen's dietary, it was relatively higher, whether compared with the protein or with the energy which the two dietaries contained. It is of considerable importance to note that the proportion of iron to protein is as high in practically all the mixed dietaries as it is in meat, so that an increased consumption of lean meat, while raising the absolute weight of iron in the dietary, would not increase the proportion of iron to protein. Eggs increase this proportion somewhat, but not to so great an extent as do many foods of vegetable origin, including the ordinary fruits and vegetables and such cereal products as include the outer layers of the grain. In cases such as may often occur in practical dietetics where it is desired to increase the iron content of a dietary already sufficiently high in protein the vegetable foods rich in iron are evidently much to be preferred to meat. If eggs are to be used in such cases, the whites may be omitted with practically no loss of iron. The results of the experimental dietary study show that it is entirely feasible to select a diet rich in iron both absolutely and as compared with protein and energy by the use of cereals, fruits, and vegetables without greater cost than for the ordinary mixed diet.

SUMMARY.

The human body of 60 to 70 kilograms is supposed to contain about 3 to 3.5 grams of iron, the greater part of which exists as a constituent of the hemoglobin of the red blood corpuscles, while much of the remainder is contained in the chromatin substance of the cells. Iron is probably an essential constituent of all nucleoproteids. The iron compounds of the body are therefore very prominent in the general metabolism and oxidative processes of the organism as a whole, and apparently also in the particular activities of the secreting and other specialized cells.

Notwithstanding the constant and varied activities of the iron compounds in the body, the amount of iron so metabolized as to be eliminated is small—in fasting experiments, 7 to 8 milligrams; in metabolism experiments with restricted diet, 5.5 to 12.5 milligrams per day. Hence the daily waste of iron probably amounts to only two or three parts per 1,000 of that contained in the body. The small amounts of iron katabolized and eliminated are normally replaced by the organic iron compounds of the food. The food-iron is absorbed from the small intestine, deposited mainly in the liver, spleen, and bone marrow, and is finally eliminated almost entirely through the intestinal walls, only a very small proportion leaving the body by way of the kidneys.

Inorganic compounds of iron given by the mouth are also absorbed to a considerable extent in the small intestine and stored in the same organs and eliminated by the same paths as the food-iron. To what extent the inorganic iron thus absorbed is actually assimilated and utilized by the body to replace the iron of hemoglobin and chromatin is still a disputed question. Undoubtedly the administration of inorganic iron may increase the hemoglobin content of the blood, especially in cases of anemia, but it is held by many and probably most of the best authorities that in such cases the iron acts by stimulating the blood-forming organs rather than by actually entering into the composition of the blood formed.

Extended series of feeding experiments upon growing animals of different species have indicated in the great majority of cases that inorganic iron, if used at all in the production of hemoglobin in the growing animal, is greatly inferior for this purpose to the organic iron compounds of the normal food. Practically the body is dependent upon the iron of the food for the maintenance of its iron equilibrium.

Experiments to determine the amount of food-iron required for the maintenance of equilibrium in healthy men indicate that this amount is largely dependent upon the nature of the food and the

amounts of the inorganic constituents which it contains, but under ordinary conditions lies between 6 and 12 milligrams per day. Under certain conditions, however, much larger amounts appear to be necessary, and it is always to be remembered that the amount required for the maintenance of equilibrium is a minimum rather than a normal figure. Even with healthy adults it is probable, and with growing children and anemic persons it is plain, that an allowance more liberal than the minimum which suffices for maintenance is necessary for the best results. In those cases of anemia in which the iron content of the blood is greatly reduced, obviously the food must furnish sufficient iron to allow for considerable storage of this element before normal conditions can be regained. In such cases the regeneration of hemoglobin is often stimulated by inorganic iron, but, according to Abderhalden, the effect of inorganic iron is greater the greater amount of food-iron supplied. While there is still some doubt as to the relative effect of medicinal and food-iron, the greater part of the experimental work emphasizes the importance of the latter, and indicates that it is often desirable to select food with reference to the amount of iron which it contains.

It addition to this it has been shown by Herter that anemic conditions are frequently associated with excessive intestinal putrefaction, so that the selection of food should be such as to combat this putrefaction at the same time that the supply of food-iron is increased.

Approximate estimates of the iron contents of 20 American dietaries regarded as typical show a minimum of 7 milligrams per man per day in the case of a negro family in Alabama and a maximum of 35 milligrams in the food of Maine lumbermen at very active work combined with exposure to cold. The majority of dietaries furnish 11 to 19 milligrams of iron per man per day. Throughout the 20 dietaries the amounts of iron run nearly parallel with the amounts of protein, the milligrams of iron per 100 grams of protein in the diet varying only from a minimum of 15 to a maximum of 20. The relation of iron to protein is thus practically the same in ordinary mixed diet as in meat, so that the addition of meat to a mixed diet does not make it richer in iron relatively to protein.

Increase of iron in the diet without a corresponding increase of protein is readily accomplished by the use of vegetables, fruits, and the coarser mill products of the cereal grains. In the experimental dietary here reported the free use of such foods with milk but without meat or eggs resulted in an increase of 30 per cent in the iron content of the diet, while the protein, the fuel value, and the cost remained practically the same as in the ordinary mixed diet obtained under the same market conditions.

O

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN—Continued.

Bul. 116. Dietary Studies in New York City in 1896 and 1897. By W. O. Atwater and A. P. Bryant. Pp. 83. Price, 5 cents.
Bul. 117. Experiments on the Effect of Muscular Work upon the Digestibility of Food and the Metabolism of Nitrogen. Conducted at the University of Tennessee, 1899–1900. By C. E. Wait. Pp. 43. Price, 5 cents.
Bul. 121. Experiments on the Metabolism of Nitrogen, Sulphur, and Phosphorus in the Human Organism. By H. C. Sherman. Pp. 47. Price, 5 cents.
Bul. 126. Studies on the Digestibility and Nutritive Value of Bread at the University of Minnesota in 1900–1902. By Harry Snyder. Pp. 52. Price, 5 cents.
Bul. 129. Dietary Studies in Boston and Springfield, Mass., Philadelphia, Pa., and Chicago, Ill. By Lydia Southard, Ellen H. Richards, Susannah Usher, Bertha M. Terrill, and Amelia Shapleigh. Edited by R. D. Milner. Pp. 103. Price, 10 cents.
Bul. 132. Further Investigations among Fruitarians at the California Agricultural Experiment Station. By M. E. Jaffa. Pp. 81. Price, 5 cents.
Bul. 136. Experiments on the Metabolism of Matter and Energy in the Human Body, 1900–1902. By W. O. Atwater and F. G. Benedict, with the cooperation of A. P. Bryant, R. D. Milner, and Paul Murrill. Pp. 357. Price, 20 cents.
Bul. 141. Experiments on Losses in Cooking Meat, 1900–1903. By H. S. Grindley and Timothy Mojonnier. Pp. 95. Price, 5 cents.
Bul. 143. Studies on the Digestibility and Nutritive Value of Bread at the Maine Agricultural Experiment Station, 1899–1903. By C. D. Woods and L. H. Merrill. Pp. 77. Price, 5 cents.
Bul. 149. Studies of the Food of Maine Lumbermen. By C. D. Woods and E. R. Mansfield. Pp. 60. Price, 10 cents.
Bul. 150. Dietary Studies at the Government Hospital for the Insane, Washington, D. C. By H. A. Pratt and R. D. Milner. Pp. 170. Price, 15 cents.
Bul. 152. Dietary Studies with Harvard University Students. By Edward Mallinckrodt, jr. Pp. 63. Price, 5 cents.
Bul. 156. Studies on the Nutritive Value of Bread and of Macaroni at the University of Minnesota, 1903–1905. By Harry Snyder. Pp. 80. Price, 5 cents.
Bul. 159. A Digest of Japanese Investigations on the Nutrition of Man. By Kintaro Oshima. Pp. 226. Price, 15 cents.
*Bul. 162. Studies on the Influence of Cooking upon the Nutritive Value of Meats at the University of Illinois, 1903–1904. By H. S. Grindley and A. D. Emmett. Pp. 230. Price, 15 cents.
Bul. 175. Experiments on the Metabolism of Matter and Energy in the Human Body. By F. G. Benedict and R. D. Milner. Pp. 335. In press.

FARMERS' BULLETINS.

Bul. 34. Meats: Composition and Cooking. By C. D. Woods. Pp. 32.
Bul. 74. Milk as Food. Pp. 39.
Bul. 85. Fish as Food. By C. F. Langworthy. Pp. 37.
Bul. 93. Sugar as Food. By Mary H. Abel. Pp. 27.
Bul. 112. Bread and the Principles of Bread Making. By Helen W. Atwater. Pp. 39.
Bul. 121. Beans, Peas, and other Legumes as Food. By Mary H. Abel. Pp. 39.
Bul. 128. Eggs and their Uses as Food. By C. F. Langworthy. Pp. 36.
Bul. 142. Principles of Nutrition and Nutritive Value of Foods. By W. O. Atwater. Pp. 48.
Bul. 182. Poultry as Food. By Helen W. Atwater. Pp. 40.
Bul. 203. Canned Fruit, Preserves, and Jellies: Household Methods of Preparation. By Maria Parloa. Pp. 32.
Bul. 234. The Guinea Fowl and Its Use as Food. By C. F. Langworthy. Pp. 24.
Bul. 249. Cereal Breakfast Foods. By C. D. Woods and H. Snyder. Pp. 36.
Bul. 256. Preparation of Vegetables for the Table. By Maria Parloa. Pp. 48.

CIRCULAR.

Circ. 46. The Functions and Uses of Food. By C. F. Langworthy. Pp. 10.

SEPARATES.

Dietaries in Public Institutions. By W. O. Atwater. Reprinted from Yearbook of Department of Agriculture for 1891. Pp. 18.
The Cost of Food as Related to its Nutritive Value. By R. D. Milner. Reprinted from Yearbook of Department of Agriculture for 1902. Pp. 19.
Wheat Flour and Bread. By Harry Snyder and Chas. D. Woods. Reprinted from Yearbook of Department of Agriculture for 1903. Pp. 20.
The Respiration Calorimeter. By W. O. Atwater and F. G. Benedict. Reprinted from Yearbook of Department of Agriculture for 1904. Pp. 16.
Scope and Results of the Nutrition Investigations of the Office of Experiment Stations. Reprinted from Annual Report of the Office of Experiment Stations for the year ended June 30, 1901. Pp. 50.
Dietary Studies of Groups, Especially in Public Institutions. By C. F. Langworthy. Reprinted from Annual Report of the Office of Experiment Stations for the year ended June 30, 1902. Pp. 34.
Nutrition Investigations at the Government Hospital for the Insane, Washington, D. C. By W. O. Atwater. Reprinted from Annual Report of the Office of Experiment Stations for the year ended June 30, 1903. Pp. 14.
Dietetics in Relation to Hospitals for the Insane. By W. O. Atwater. Reprinted from Annual Report of the Office of Experiment Stations for the year ended June 30, 1904. Pp. 24.
Investigations on the Nutrition of Man in the United States. By C. F. Langworthy and R. D. Milner. Pp. 20. Document No. 713.